W. B. No. 743

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CHARLES F. MARVIN, Chief

U.S. weather review

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions, and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables, dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (a) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (b) abstracts or reviews of important meteorological papers and books; and (c) notes. In each issue of the REVIEW abstracts, reviews, and notes are grouped by subjects, roughly, in the following order: General work, observations, and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but **the publication of contributions is not to be construed as official approval of the views expressed.**

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. *Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.,"* in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW OR SUPPLEMENTS.

The section of the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
Meteorological and Seismological Service of Mexico.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS, containing kite observations, and others containing monographs or specialized groups of papers, are published from time to time.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. An addressed franked slip may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.
SUPPLEMENT, No. 3.

MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

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W. B. No. 743.

JUNE, 1921.

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KONA STORMS.

By LAWRENCE H. DAINGERFIELD, Meteorologist.

[Weather Bureau, Hononlulu, Hawaii, Apr. 23, 1921.]

SYNOPSIS.

"Kona," or southerly, winds over Hawaii are believed to be local phases of reversed or disturbed pressure distribution over the north Pacific. Five principles are stated in support of this theory. A review of the December 22-28, 1920, kona storm is given, in demonstration of the theory, supported by several maps. A list of kona storms from 1914 to date is given in tabular form.

The word "kona" is of Polynesian origin, meaning "leeward." The Hawaiians of antiquity had no words to indicate the points of the compass. When asked the direction to a certain place, they would say "mauka" or "makai"—meaning "mountainward" or "toward the sea." Possibly they would use the well-known local geographical expressions of "Ewa" or "Waikiki," meaning in the direction of those two suburbs of Honolulu.

In like manner the kona storm received its name, meaning in its simplest form that the leeward sides of the several islands of Hawaii had become temporarily the windward sides. The northeast or trade wind is dominant throughout the Territory. Consequently, the term "kona" applies to southerly or southwesterly winds.

The literature on kona storms is extremely meager, despite the fact that these peculiarly Hawaiian storms are of relatively frequent occurrence and were early recognized as prominent phenomena and of vital importance to the drier sections of the several islands. It is a well-established fact that many broad areas of Hawaii, in the drought-stricken shadows of the sheltering hills and mountains, acting as barriers to the trades, would be nothing but desert wastes, except for the somewhat fortuitous coming of the kona storms.

These storms are not unmixed blessings, however. Trees, crops, agricultural lands, homes, and whole villages, have been washed away at times, with resultant life and property loss. Forests have been flattened by the attendant winds and leeward harbors and coast lines rendered dangerous to shipping on the sea. Counting both profit and loss, however, it has been found that the balance is largely advantageous to the communities visited by these storms.

In view of the preliminary remarks, it may seem presumptuous on the part of the writer to attempt a solution of the kona-storm riddle, placing it on the way to a scientific solution. Nevertheless, we attempted a presentation of our first study of konas before the Pan-Pacific Scientific Conference, held in Honolulu last August. The accumulation of observed facts since the preparation of the paper of last August has tended to substantiate the views then expressed relative to the cause of konas.

The phenomenon of kona storms appears to rest on the following five basic meteorological facts:

1. The Hawaiian Islands lie just south and southwest of the great north Pacific high-pressure area. The center of this high-pressure area reaches its farthest north and west position, slightly to the north of the 40th parallel and near 150°, west longitude, during July, August, and September. The central region of high pressure, however, is between 30° and 40°, north latitude, and to the east of the 140th meridian during the colder months—from November to February, especially.

2. The high-pressure area is most enduring and reaches its maximum strength during the warm months, with August as its peak month, at the time of its most northern and western position. This fact is in complete harmony with another well-known fact, namely: That land masses acquire and lose heat much more rapidly than do the vast oceanic areas. The continent of North America is consequently under low-pressure dominance in summer, while a considerably higher pressure prevails over the cooler north Pacific.

3. Inasmuch as the direction and force of wind depend upon the relative position of high and low pressure areas, and the steepness of the intervening pressure gradient, we find the time of the most persistent trade winds to be during the warm months of the year. The earth's rotation causes the trades to assume a more nearly east-west course as the equatorial low-pressure belt is approached.

4. Conversely, we find the colder months, when the north Pacific high area is weakest and drawn closest to the United States coast, that the trades are most fickle. There are occasions, indeed, when they are suppressed over Hawaii and counter, or southerly, winds spring up, indicating that a reversal in trend of the pressure gradient has occurred.

5. We must introduce at this time another pressure system to explain the reversal in wind direction, noted immediately above. To the north and northwest of the north Pacific high area lies the Aleutian low-pressure area. This is a well-defined and practically permanent depression which occupies the vicinity of the Aleutian Islands during the colder months of the year; the depression disappears during the summer season.

Let us see how these facts apply to these peculiarly Hawaiian storms. Recalling that the Aleutian Islands low area reaches its greatest depth during the colder season, or months of most frequent kona storms; that this is the time when the north Pacific high area dissipates to

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a marked extent and shrinks eastward toward the California coast; we observe that the high-pressure belt lying to the north of Hawaii during the late autumn, winter, and early spring months occasionally breaks down completely. At such times the gradient, ordinarily for northeast winds, is reversed and southeast, shifting to south and southwest, winds set in over the islands beginning at the extreme northwest portion of the chain and progressing southeastward. The force of the southerly winds and their duration is of course dependent upon the magnitude and position of the barometric depression. It seems probable that the latter extends southwestward from the Aleutian LOW in the form of a trough or V-shaped depression. Frequently three or four days are required for these southerly winds to swing across the eight larger islands of Kauai, Niihau, Oahu, Molokai, Lanai, Kahoolowe, Maui, and Hawaii, attended by moderate to heavy precipitation.

These migrating, wet, southerly winds are the typical konas of Hawaii—merely local phases of vast barometric depressions. Thus, the ordinarily dry, leeward slopes become temporarily the windward slopes and are deluged with water. The more directly these southerly winds strike the steep slopes of the hills and mountains, known locally as "palis," the quicker and freer the condensation and the more torrential the precipitation.

The most pronounced kona storm experienced in Hawaii since the inauguration of forecasting, about one year ago, occurred during the period of December 22–27, 1920. For example, on Oahu with 37 rainfall reporting stations the amount and distribution of rain December 21 to 26 may be seen from the small table below:

Dates.	Number of rain reports.	Average amount (inches).	Dates.	Number of rain reports.	Average amount (inches).
Dec. 21	12	0.22	Dec. 24	37	4.15
Dec. 22	14	.91	Dec. 25	32	.98
Dec. 23	36	3.12	Dec. 26	26	.03

The first hint of this storm came from Midway Island, p. m., December 20, when the pressure had fallen to 29.84 inches. By the evening of the 22d, the pressure at Midway had fallen to 29.36 inches, with the wind veering to the west and reaching a maximum velocity of 38 miles from the west. The pressure rose slowly to 29.46 by the evening of the 23d, on which date the wind velocity reached a maximum of 72 miles from the northwest—a record for the station. Thereafter the pressure rose slowly at Midway, although oscillating somewhat, until normal pressure was again reached on the 28th. Westerly winds prevailed throughout the time of rising barometer at Midway. Upon the arrival of the Commercial Pacific Cable Co. schooner *Flaurence Ward* from Midway Island, Capt. George H. Piltz, of that ship, supplied us with valuable meteorological data. A copy of *Flaurence Ward* weather log, December 21 to 25, 1920, appears in table No. 2 below.

It appears that when the ship was in north latitude 27° 40′ and west longitude 167° 30′ at 1:30 a. m., 157° 30′, meridian or Honolulu time, December 22, her barometer read 29.75 and the wind was from the east-northeast, with force 5. Thereafter the pressure fell rapidly, with a veering wind through the east, southeast, south, to southwest during the next three days. The lowest pressure reached was 29.10 inches at midnight, December 23–24, in latitude 27° 40′ north and longitude 166° 15′ west, at which time the wind was in the south-southwest, and reaching a force of 11 shortly thereafter. Terrific lightning and heavy rain were experienced during the evening of the 22d, and squalls and lightning from 4 a. m. of the 23d to noon of the 24th. The quick veering of the wind from southeast to south-southwest, during the 22d, indicates that the region of low pressure was extremely narrow and that the schooner was relatively near the southern tip of a V-shaped depression.

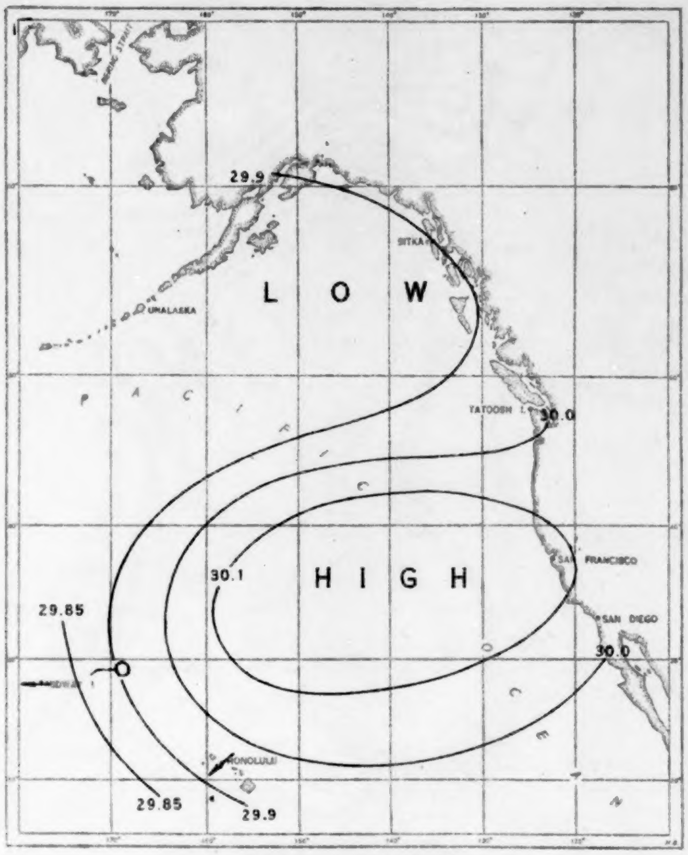
At Honolulu, the wind veered from northeast to east between 6 and 7 a. m.; to southeast, between 8 and 9 a. m., and to south, between 5 and 6 p. m., December 22d. Rain began at 7:55 p. m. of 22d, continuing with slight intermissions until 6:15 a. m., 25th; the heaviest fall was on the 23d, and the lowest pressure, 29.73 inches, was reached at 3:10 p. m. of the 24th. The wind veered into the southwest during the evening of the 24th and into the west between 5 and 6 a. m., of the 25th, after which time the rain ceased and the weather improved and the kona was practically over, although cloudy throughout the day. The maximum velocity of the wind was 36 miles from the west at 5:18 a. m., December 25. By the evening of the 25th, the wind had veered into the northeast quadrant and the pressure was approaching normal.

Judging by the time of the beginning and ending of the general rain over the several islands, we find that the kona storm under consideration began over Kauai early on the 22d and ended over Hawaii on the 28th of December—taking six days in its passage over the islands, which is slower than the average time, as shown by the accompanying table of kona storms, 1914, to date.

An examination of the weather maps of the North Pacific Ocean shows the apparent swinging southward* of the Aleutian Islands low area from December 20 to 24, and then its northward swing thereafter until reaching its normal position about the 28th.

Inspection of the accompanying table of kona storms will show that these southerly rainstorms, with few exceptions, reach Kauai, the northwesternmost of the main Hawaiian Islands, first, and Hawaii, the southeasternmost, last, in harmony with the southern or southeastern swing of the Aleutian Islands depression, at the season when it is most active, and when the north Pacific high-pressure area is least permanent and nearest the southern California coast. Occasionally, only a part of the islands of the group are affected by a kona storm, at which times only the northernmost. There have been exceptions to this rule, however, indicating that either the Aleutian Islands depression had spread southward to the east of Kauai, or there had been a development of a barometric depression somewhere to our northeastward in the oceanic area normally occupied by the north Pacific high-pressure area.

*It is preferred to think of Kona storms as independent developments, possibly as a result of the eastward movement of cyclonic systems in higher latitudes in which the center and the northern portion of the cyclone advance more rapidly than the southern and eventually merge with the semi-permanent Aleutian Low, rather than a bodily shifting of the latter to the southwest. Doubtless the configuration of the isobars in the Aleutian Low changes from day to day as cyclones advance from the west or issue toward the east-southeast. Such changes need not be considered as indicating a temporary shifting of the LOW itself.—EDITOR.



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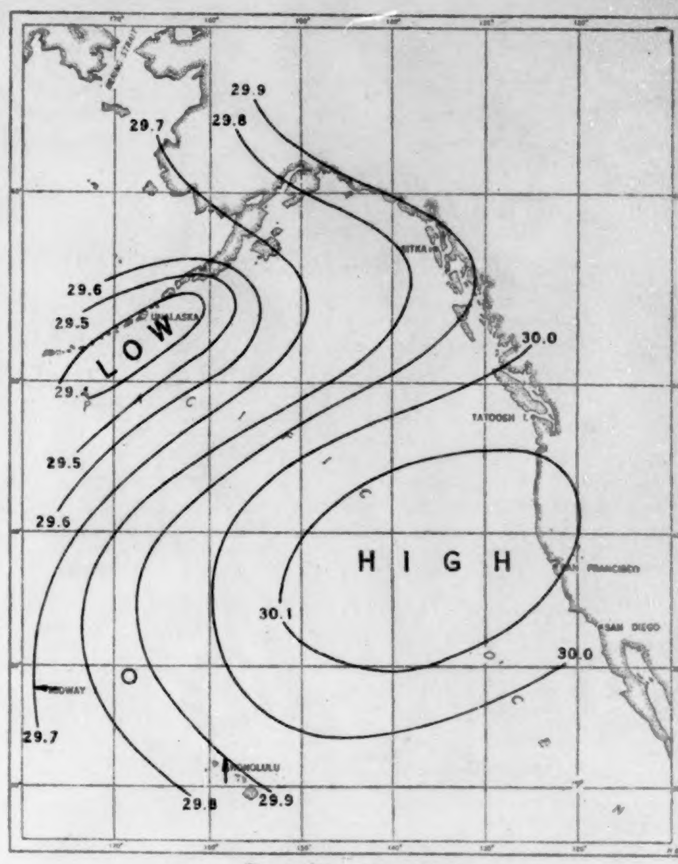

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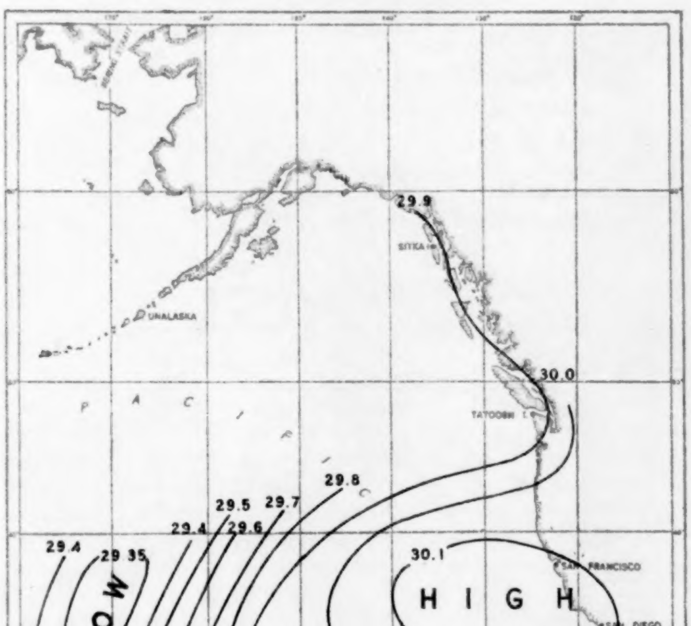

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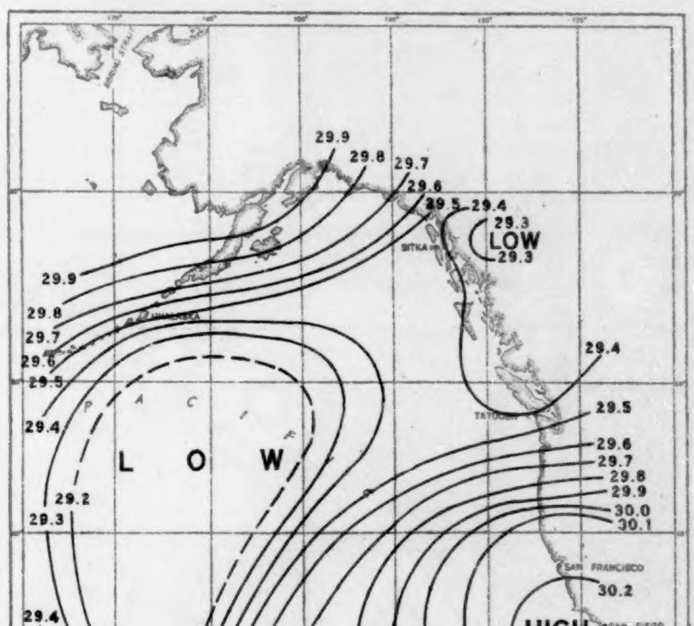

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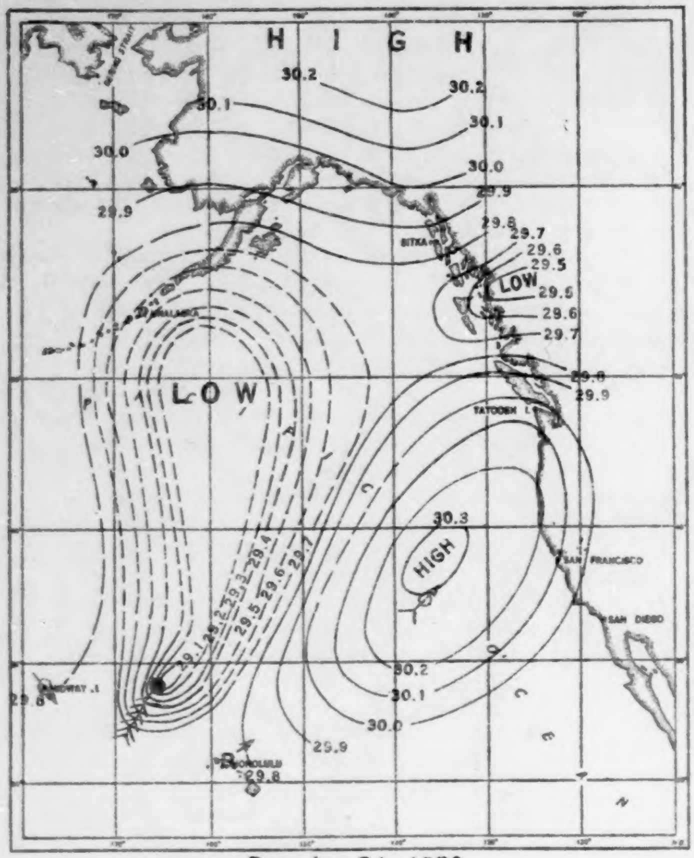
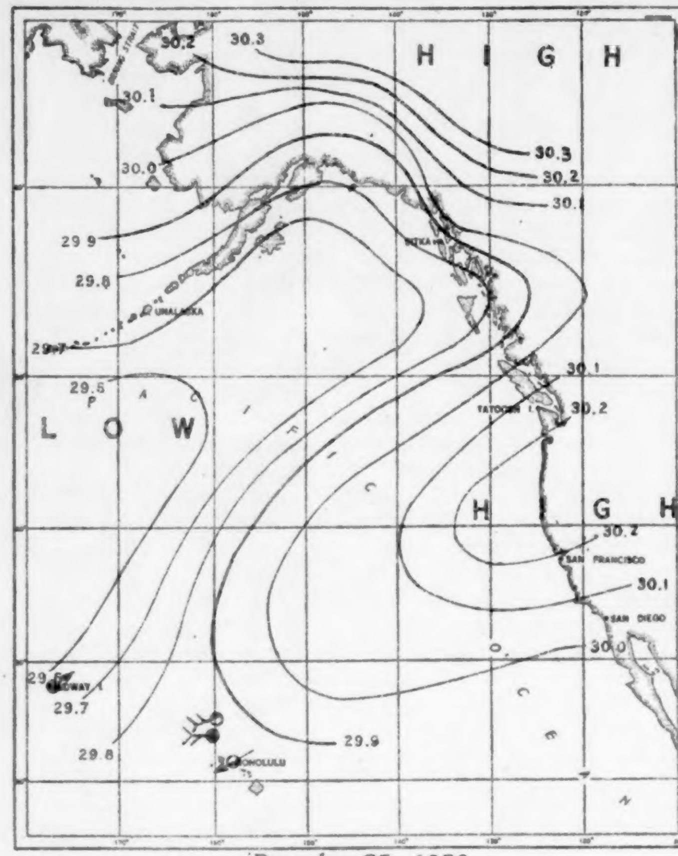
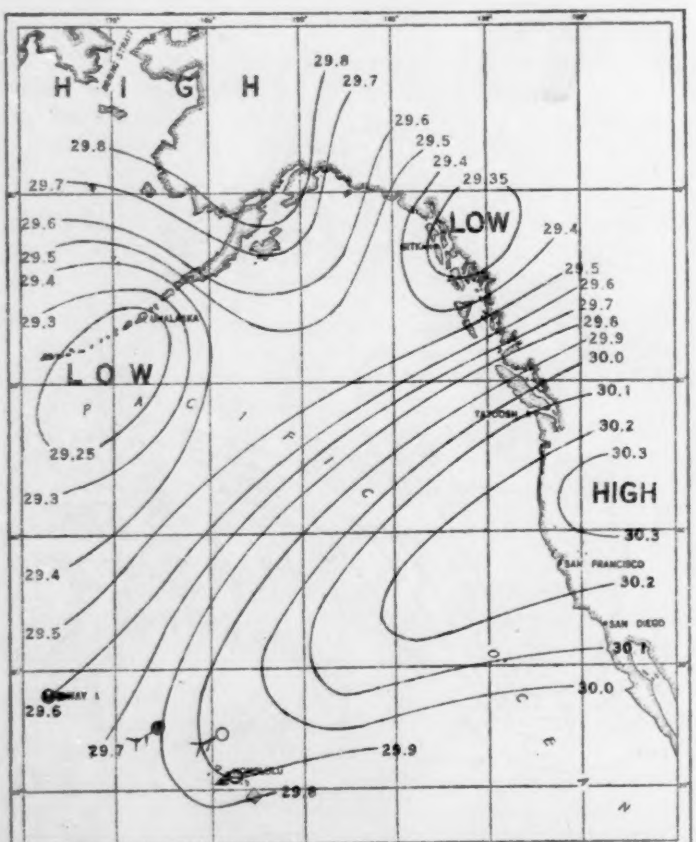


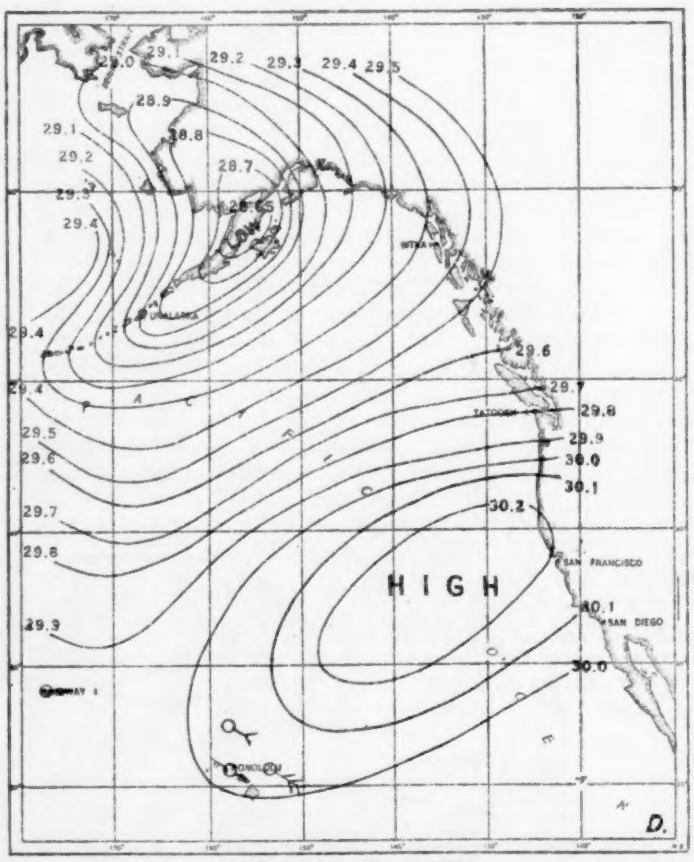
December 24, 1920



December 25, 1920



December 26, 1920



December 27, 1920

TABLE 1.—*Kona storms, March, 1914, to February, 1921, both inclusive.*

PRESSURE, WIND, AND PRECIPITATION DATA FOR HONOLULU.

Date.	Lowest pressure.	Wind.			Total rain.	Remarks.
		Maximum velocity.	Direction.	Prevailing direction.		
1914.	*Inches.*	*Miles.*			*Inches.*	
Mar. 27	....	14	SE.	SE.	0.09	Rain began Hawaii, 24th.
28	29.82	24	S.	S.	2.55	Rain ended Hawaii, Maui, Oahu, 29th.
Dec. 18	....	22	SW.	SW.	0.00	Rain began Kauai, Oahu, 19th.
19	29.60	34	S.	SW.	1.53	Rain ended Hawaii, 22d.
1915.						
Nov. 11	29.82	21	S.	S.	1.04	Beginning and end of rain not clear; lowest pressure on 10th.
12	....	10	NE.	S.	1.78	
Dec. 23	....	8	S.	E.	0.00	
24	....	27	SE.	SE.	0.40	Rain began Kauai.
25	....	41	S.	SW.	2.82	
26	29.72	31	S.	SW.	0.33	
27	....	34	SE.	SE.	1.37	Rain ended Kauai, Oahu, 29th.
1916.						
Jan. 16	....	35	SE.	S.	0.00	Rain began Kauai.
17	29.64	49	SW.	S.	2.02	
18	....	51	SW.	SW.	4.24	
19	....	47	W.	SW.	0.78	Rain ended Hawaii, 21st.
Jan. 23	....	16	SE.	SE.	0.00	Rain began Kauai.
24	29.86	18	SE.	SE.	0.00	
25	....	32	S.	SE.	1.53	
26	....	48	S.	NW.	0.94	Rain ended Hawaii, 28th.
Mar. 3	....	19	SE.	SE.	0.01	Rain began Kauai, 1st.
4	29.68	28	W.	SE.	3.30	
6	....	32	SW.	S.	0.58	Rain ended Hawaii, Maui, 8th.
1917.						
Jan. 9	....	25	SW.	S.	0.59	Rain began Kauai.
10	29.80	30	SW.	SW.	2.07	Rain ended Hawaii, Maui, 12th.
Jan. 19	29.81	31	SE.	SE.	1.52	Rain began Kauai, 15th.
20	....	29	SE.	SE.	0.90	Rain ended Kauai, 20th, Oahu, 21st.
Mar. 19	29.70	26	SW?	SE.	8.76	Lowest pressure, 18th.
20	....	23	NE.	E.	4.78	Rain ended Kauai, 22d.
1918.						
Jan. 18	....	32	SW.	SW.	1.21	Rain began all islands; ended 20th.
19	29.78	42	SW.	SW.	0.31	
Apr. 18	....	17	S.	SE.	0.03	Rain began Kauai.
19	29.85	23	SE.	SE.	3.76	Rain ended Hawaii, 22d.
Nov. 24	....	20	S.	SE.	0.70	Rain began Kauai.
25	29.75	39	S.	S.	3.63	
1919.						
Dec. 2	....	19	S.	E.	T.	Rain began Kauai.
3	....	37	S.	SE.	0.26	
4	29.74	20	SW.	W.	0.13	Rain ended Hawaii, 5th; Oahu, 6th.
1920.						
Jan. 9	....	31	S.	S.	T.	Rain began Kauai.
10	....	32	W.	W.	0.48	
12	....	15	SW.	W.	T.	
13	....	21	S.	S.	0.30	
14	....	15	S.	SE.	T.	
15	....	16	SW.	S.	0.00	
16	....	18	S.	NE.	0.72	
17	29.58	25	NW.	NE.	2.08	Rain ended Hawaii, Maui, Oahu, 18th.

TABLE 1.—*Kona storms, March 1914, to February, 1921, both inclusive*—Continued.

PRESSURE, WIND, AND PRECIPITATION DATA FOR HONOLULU—Contd.

Date.	Lowest pressure.	Wind.			Total rain.	Remarks.
		Maximum velocity.	Direction.	Prevailing direction.		
1920.	*Inches.*	*Miles.*			*Inches.*	
Apr. 16	....	16	S.	NE.	0.00	
17	29.94	16	S.	S.	0.01	Rain began Kauai.
18	....	22	S.	S.	0.25	Rain ended Oahu, 23d; questionable weather touched Hawaii.
Dec. 22	....	25	S.	SE.	0.11	Rain began Kauai.
23	....	33	S.	SE.	4.57	
24	29.73	33	S.	S.	1.16	
25	....	36	W.	W.	0.37	Rain ended Hawaii, 28th.
1921.						
Feb. 17	....	33	W.	S.	0.12	Rain began Hawaii, 15th.
18	29.79	13	S.	S.	0.33	
19	....	18	S.	S.	0.82	
20	....	21	S.	S.	T.	
21	....	31	W.	SW.	0.23	Rain ended Kauai.
22	....	30	SW.	W.	0.03	Rain ended Oahu.

TABLE 2.—*Log of the schooner "Flaurence Ward," Midway Island to Honolulu, Dec. 21–25, 1920 (157° 30′ meridian time).*

Date.	Time.	Position.		Barometer.[1]	Attached thermometer.	Wind.		Remarks.
		N. lat.	W. long.			Direction.	Force.	
		° ′	° ′	*Inches.*	*°F.*			
Dec. 21	1:30 a. m....	28 48	168 29	29.90	68	Calm.	0	Rolling sea.
22	1:30 a. m....	27 40	167 30	29.75	69	ENE.	5	
	4 p. m........	....	....	29.60	....	SE.	4	Lightning.
	6:30 p. m....	....	....	29.53	....	S.	4	
	8 p. m........	....	....	29.50	....	SSW.	5	Terrific lightning.
	12 midnight.	....	....	29.40	....	SSW.	....	Heavy rain.
23	1:30 a. m....	27 42	166 23	29.30	69	SSW.	8	Rough sea.
	4 a. m........	....	....	29.30	....	SSW.	....	Squally and lightning.
	8 a. m........	....	....	29.30	....	SSW.	8	Squally.
	Noon........	....	....	29.28	....	SSW.	8	Do.
	4 p. m........	....	....	29.20	....	SSW.	9	Do.
	12 midnight.	27 40	166 15	29.10	69	SSW.	10	Do.
24	1:30 a. m....	....	....	29.10	69	SSW.	10	Do.
	4 a. m........	....	....	29.10	....	SSW.	10	Do.
	8 a. m........	....	....	29.20	....	SSW.	11	Do.
	Noon........	....	....	29.26	....	SSW.	11	Do.
	4 p. m........	....	....	29.32	....	SW.	10	
	8 p. m........	....	....	29.40	....	SW.	8	
	12 midnight.	....	....	29.50	....	SW.	6	
25	1:30 a. m....	26 27	161 58	29.52	69	SW.	9	Rough sea; barometer rose slowly as wind died down; wind did not shift in squalls; finished in direction in which it started, ENE.

[1] Aneroid barometer compared at station upon return to Honolulu and found correct.

GENERAL SURVEY OF METEOROLOGICAL PROBLEMS OF PAN-PACIFIC COUNTRIES.[1]

By LAWRENCE H. DAINGERFIELD, Meteorologist.

[Weather Bureau, Honolulu, Hawaii, Oct. 28, 1920.]

The Pacific Ocean embraces an area of about 55,000,000 square miles, equivalent to the entire land surface of the globe, and presents to the meteorologist, partly by reason of this vast extent, many features of great interest and importance. In regard to some of these we are already more or less well informed, but of others our knowledge is very meager and many important questions concerning them remain to be answered.

The coordinated efforts of the several nations whose lands lie within or about the far-reaching borders of the Pacific are essential to the proper study of these features and to success in any attempts that may be made to solve the physical problems associated therewith.

What appear to be the chief features of Pacific Ocean meteorology calling for study at the present time are presented briefly below, the object being to establish a basis for systematic investigation in the future. It is recognized, of course, that any plan made now, must necessarily be subject to modification.

The survey may be presented in the form of a series of questions:

1. What is the normal distribution of atmospheric pressure over the Pacific Ocean and its adjacent land areas?

2. What is the normal *seasonal* distribution of pressure?

3. What regions are under permanent high pressure? What under permanent low pressure?

4. What are the regions occupied by high or by low-pressure areas, in which pressure conditions vary, or indeed are reversed, with the change of season?

[1] Reprinted from *Proceedings of the First Pan-Pacific Scientific Congress.*

5. Where do typhoons originate? What is their fundamental cause?

6. What are the normal tracks of typhoons relative to their place of origin, to the season, etc.?

7. Do typhoons ultimately, say, when they enter the region of the Aleutian Islands, become normal extratropical cyclones?

8. Are the kona storms of the Hawaiian Archipelago a result of the extratropical cyclones?

9. If so, what are the circumstances of pressure distribution in the regions of the north Pacific high-pressure area and the Aleutian low-pressure area which combine to cause them?

10. What are the relations between the prevailing distribution of air pressure over the Pacific and the character of the weather in the Pacific area, such as hot or cold periods, wet or dry, extending at times over months, seasons or even years?

11. Similarly, what are the relations as affecting the weather of adjacent land areas?

12. What are the interrelations between surface winds and ocean currents?

13. What are the relations between surface-water temperatures of the Pacific and air temperatures and, consequently, the positions of "centers of action" and their shifts over that ocean and over adjacent land areas?

14. At what average elevations are the so-called antitrade winds found from place to place along the Tropics?

15. What are the diurnal, monthly, and annual variations in antitrade wind elevations?

16. What are the normal velocities of the antitrades and the departures therefrom?

17. What are the relations, if any, that exist between volcanic and seismic activity and weather changes?

18. What new facts, if any, can be established with regard to fog?

19. What steps should be taken to increase the practical application of meteorological knowledge?

20. What are the more special meteorological problems of Pan-Pacific countries?

As has been stated, some of the features of Pacific Ocean meteorology are already more or less well understood. This is true of those appearing under questions Nos. 1 to 6, inclusive. Additional knowledge in regard to these features can only result from the cooperative activities of the several Pan-Pacific nations.

Question No. 7, as to whether typhoons become extratropical cyclones, has not perhaps been satisfactorily answered and requires further study of observations from the regions lying between Japan and the Aleutian Islands. The suggestion has been made that in this as well as in other connections fixed or semifixed vessel weather stations should be employed in the less frequented regions to supplement reports from vessels on the established trade routes.

Questions Nos. 8 and 9 are in a fair way to be answered. Results might be hastened by the inauguration of the proposed system of vessel weather stations, which would make available data from certain untraveled waters.

Questions Nos. 10 and 11 may be answered as a result of the same methods of study but a longer period of time, possibly several or many years, may be required in so doing.

Questions Nos. 12 and 13 have been given general consideration for many years. The making of more widespread observations and of a more specific study of the temperatures of the ocean surface water and of the temperatures, pressures, and winds in the Pacific region appear to be necessary before No. 13 can be answered.

Questions relating to the antitrade winds, comprised in Nos. 14, 15, and 16 have been considered only slightly and before they can be answered many pilot and sounding balloon observations will be required, as well as observations from land stations of high elevations along the Tropics.

Question No. 17, likewise, has received but slight attention. A long series of meteorological, volcanological and seismological observations throughout the Pan-Pacific region and a comparative study of the same will be required before an answer can be made to this question.

The specific meteorological problems of the several Pan-Pacific countries, referred to under the head of question No. 20, are so varied and complex that their presentation would go beyond the scope of this general survey and therefore no attempt is made to enumerate them. However, without knowing what these problems may be it is reasonable to assume that under the plan of intimate and hearty cooperation evolved at the Pan-Pacific Congress the mere suggestion on the part of any one nation of a desire for aid from other member nations will meet with a quick and intelligent response.

If methods of procedure were to be suggested at this time they would doubtless be based upon such general concepts as uniform scales and measures, synchronized observations, both on land and sea, standardized codes and signals, the more prompt exchange of reports, including a larger daily exchange, and a more liberal policy with respect to the translation from one language to another of books and papers on meteorological subjects.

METEOROLOGICAL CENTERS OF ACTION IN THE NORTH PACIFIC OCEAN.[1]

By EDWARD A. BEALS, Meteorologist.

[Author's abstract.]

Since Teisserenc de Bort first called attention to the "centers of action" over Iceland and the Aleutian chain of islands, much study has been given the subject. It has been found that, besides these centers of action or LOWS, the permanent HIGHS over the Atlantic, Pacific, and Indian Oceans, and the winter HIGHS and summer LOWS over the continents are modifying factors.

The Pan-Pacific Conference is of interest to meteorologists because of the proposed scientific survey of the Pacific Ocean. Two powerful centers of action are located in the north Pacific.

It had previously been noted that falling pressure in the Iceland LOW produced warmer, and rising pressure colder weather in central and northwestern Europe. Reasoning from analogy, similar changes in the Aleutian LOW should produce corresponding changes in weather over North America.

The late Prof. Garriott maintained that when the depression over the Aleutians is abnormally low the north Pacific HIGH increases in size and overlaps the southwestern coast of the United States, causing temperatures below the seasonal average there. Offshoots from the Aleutian LOW would then take a northern route in their progress eastward, and large areas in the United States would come under the influence of southerly winds, and the resulting weather would be unseasonably mild. Many

[1] Presented before Pan-Pacific Scientific Conference, Honolulu, Hawaii, August, 1920, and published in full in the *Proceedings* of the conference, 1921.

examples of extreme weather conditions during the past 30 years seem to verify Prof. Garriott's conclusions.

Maj. E. H. Bowie, who has also given the subject considerable attention, has formulated many rules of value in forecasting. The two of perhaps the most consequence are the following:

"With high pressure over Alaska, more precipitation than usual occurs in the United States."

"Cold waves of more than short duration do not occur when the barometer is low over Alaska, whereas intensely cold weather over the United States east of the Rocky Mountains is generally associated with high barometer over Alaska."

The north Pacific HIGH forms where it does because of three conditions: (1) Differences in temperature between the north polar and the equatorial regions; (2) deflection of winds due to the rotation of the earth on its axis; and, (3) the ocean surface is coldest near the latitude where causes 1 and 2 operate to produce the formation of the HIGH.

It is assumed by the forecasters of the San Francisco Weather Bureau office that when the summer temperature in that city is above normal the north Pacific HIGH is weaker than usual, and when the summer temperature is below normal the contrary conditions exists. Dr. G. F. McEwen explains the cool waters off the north California coast as being due to the upwelling of cold waters. The prevailing westerly winds at San Francisco will be relatively warm or cool in accordance with the condition of the surface waters over which they blow before reaching the city.

When the north Pacific HIGH is weak, few, if any, offshoots will move eastward across the north Pacific States, and the pressure will be below normal in the interior of the country west of the Continental Divide. This will result in prolonged, unsettled weather without much rain, but with more than the usual amount of cloudiness. On the other hand, if the North Pacific HIGH is strong there will be offshoots from it crossing the north Pacific States with considerable regularity, and the weather will be settled and clear, with warm days and cool nights over a large portion of the Pacific Slope.

Ocean currents move slowly, and if it is possible to determine the temperature of the water off the California coast at or near where they are upwelling most strongly, then we would know two or three months in advance whether or not ocean currents fed by these waters would be warmer or cooler than usual. Such information would be of great value.

The Aleutian LOW is caused by a combination of the effects of the general circulation of the atmosphere and differences in temperature between the water and the mainland. It is probable that the activity of the LOW is increased when the water is warmer or the land is colder than usual. When the water is warmer than usual, observations of temperature of the Japan Current near Formosa (Taiwan) would probably give information of value by informing us three or four months beforehand that warmer water than usual was about to reach the Bering Sea. When the land becomes abnormally cold, weather reports from the interior of Siberia and Alaska are necessary. If it is possible to ascertain in advance that the Aleutian LOW is about to change its position or to become either more or less energetic, such information would have a direct bearing on the weather that later will be experienced in the United States and Canada.

In studying the movements of LOWS and HIGHS a dozen widely separated stations are insufficient. Dr. Bjerknes found when making weather predictions in Norway during the Great War he had to increase the number of stations from less than 10 to about 90 before getting worth-while results. We should have instead of 10 in the neighborhood of the Aleutian LOW as at present, no less than 100 to secure satisfactory results.

DROUGHTS WITH CIRRUS CLOUDS MOVING FROM THE NORTH.

During my many years of observations of the weather, I have always noticed that just before the beginning and during a protracted period of dry weather, the upper clouds, namely, cirrus, cirro-stratus, cirro- and alto-cumulus, which normally move from the SW., W., or WNW., suddenly change their direction and come from the NNW., N., and even NE. This was especially noted during the very recent drought in this section. At its commencement the cirrus moved abnormally fast from the NNE. During such dry periods, although the clouds may thicken to almost darkness, only a few sprinkles occur. On the other hand during conditions of ample rains, the upper cloud movement is from some southerly quarter. Surface winds are then generally from the north or east. Other observers have made similar observations especially in regard to the movement of cirrus clouds during long stretches of aridity and their tendency to move out of the North at such times.

Can not this dry condition be explained by the fact that the source of the rising air is far to the north as shown by the cirrus movement and such air coming from regions of low temperature has a low moisture content and therefore little or no rain results. When this condition is reversed and the movement of air is from the south in the upper atmosphere, copious rains fall because of the great increase of vapor capacity of air coming from these warmer regions and also for their greater buoyancy from latent heat when condensation starts.

As a general rule, when low-pressure areas are far to the north the tendency of the cirrus movements is from a northerly quadrant and vice versa, but during periods of abnormally dry or wet weather these conditions are greatly intensified and the cirrus may move rapidly or slowly from direct North or South as the conditions may be.—*Douglas F. Manning, Alexandria Bay, N. Y., June 19, 1920.*

Later note, June 10, 1921.—This district needs rain quite badly, in fact the general conditions appear very droughty. The cirrus cloud movement is as I have always observed under such conditions and which I have mentioned in other letters, "*almost directly out of the north,*" perhaps a little east of north these days. About a week ago just before the arrival of the big HIGH from the north with its polar air, the cirrus changed their direction and came out of the southwest. But a few days after their direction reversed again. It has come to my notice without fail that cirrus movement from a southerly direction accompanies cool rainy weather. Perhaps this only holds good in this part of the country.—*D. F. M.*

DISCUSSION.

By A. J. HENRY.

Mr. George Reeder's observations at Columbia, Mo., reported upon in MONTHLY WEATHER REVIEW for October, 1919, associate a movement of cirrus from some easterly point, with high temperature and drought in Missouri and other parts of the great interior valleys. In a letter from Mr. Reeder, dated June 21, 1921, he reports, in part, as follows: "For about two weeks and more, the atmosphere at the cirrus level has been in a very stagnant condition, as observed at the Columbia station. Finally cirrus clouds were observed moving from easterly points on the 11th, 15th, 17th, and 18th, and from the south on the 20th and 21st. * * *

"The surface conditions of the past 10 days have not furnished any connections apparent or reasons why the upper part of the troposphere should flow back upon itself."

In order to get as much light as possible upon the subject the aid of the Aerological Division was sought. Through the courtesy of that division the table presented below has been prepared. This table summarizes by dates all cases of the upper air currents observed moving from an easterly quarter at and above 5 km. The general impression created by a study of the data of this table is that in general interruptions to the general drift of the air at higher levels from west to east are at best local and temporary. There seems to be but little uniformity in the direction of the upper winds from the east at stations moderately close to each other except in the single case of June 19 over southern Michigan, southern Wisconsin, and northern Indiana—see the records of Lansing, Madison, and Royal Center. Even in this case the depth of the northeast layer was not uniform at the three stations, being greatest at Lansing and least at Royal Center; at Madison, moreover, a north-northwest wind was observed above the north-northeast wind.

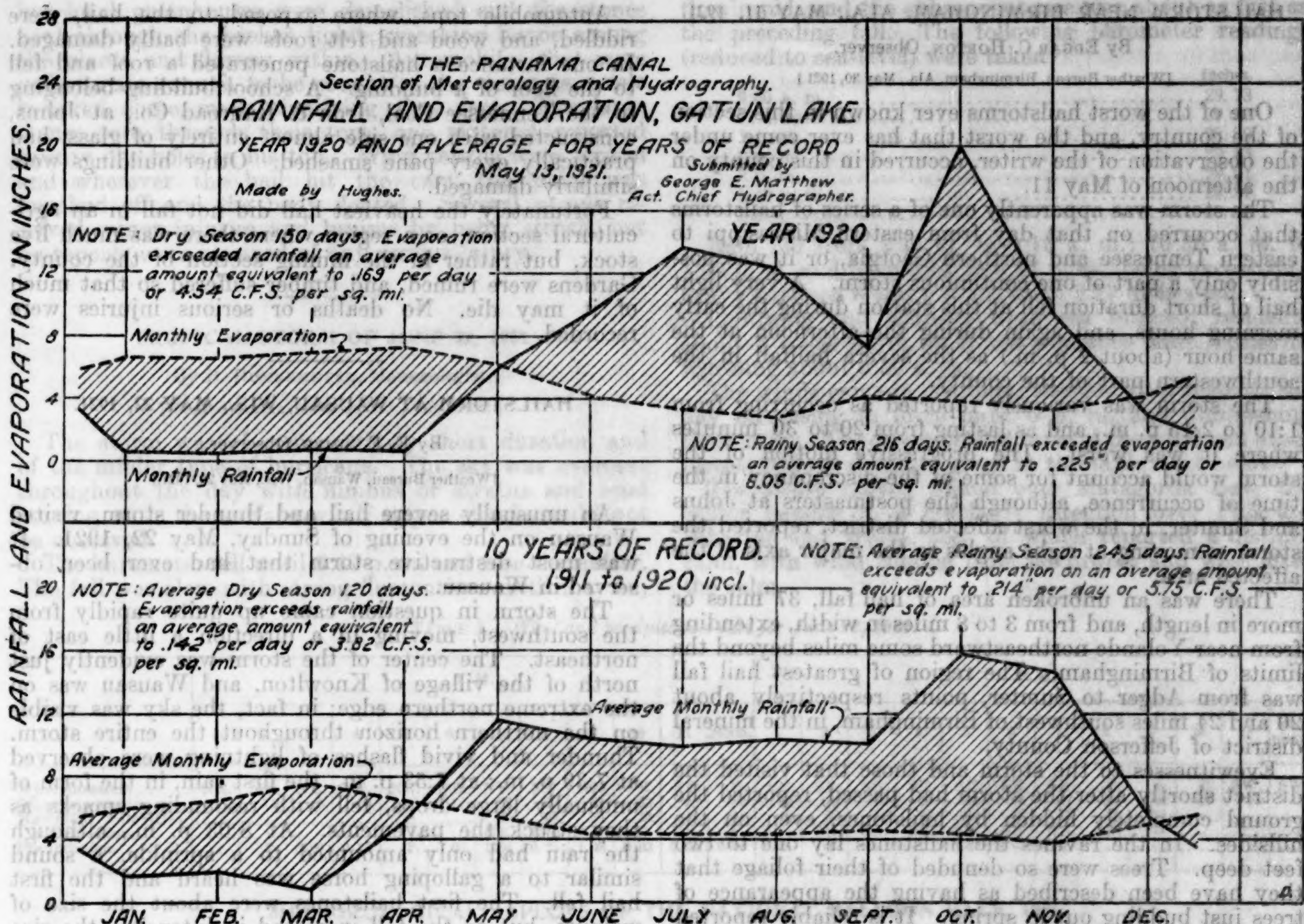
The daily weather maps for the dates on which winds from an easterly quarter were observed give little or no indication of the cause of the movement from that direction, although it seems probable that the direction observed at Broken Arrow, Okla., on the 11th, 12th, and 13th was due to the movement of an anticyclone across the State on those dates. At this same station on the 17th strong southeast winds were observed at 10 km. which may have been caused by a large anticyclone which occupied the Gulf States.

Mr. W. R. Gregg, in charge of the Aerological Division, is of the opinion that the matter of cirrus movement from the east is simply a question of latitudinal temperature distribution. If the gradient is steep, then westerly winds of high speed are found aloft; in proportion to the decrease in the latitudinal temperature gradient there is found a decrease in speed of the westerlies. If that gradient becomes *nil* or is reversed the westerlies cease and sometimes easterlies are found.[1]

[1] MO. WEATHER REV., Dec. 1919, 47: 853–854.

TABLE 1.—*Air movements from easterly directions above 5 km. at kite and balloon stations, June 10–30, 1921.*

Date, 1921.	Time (75th Mer. T.).	Station.	Surface.		5,000		6,000		7,000		8,000		9,000		10,000		11,000		12,000		13,000		14,000	
			Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.	Dir.	Vel., m. p. s.
June 10	3:39 p.	Due West, S. C.	n.	3	nne.	3	ene.	4																
	2:44 p.	Key West, Fla.	ese.	5	e.	6	ne.	5	ne.	7	ne.	8	nne.	8										
	4:05 p.	March Field, Calif.	nw.	6	ese.	8																		
11	3:35 p.	Broken Arrow, Okla.	sse.	4	ne.	10																		
	3:44 p.	Denver, Colo.	se.	5	s.	5	s.	6	s.	6	sse.	4												
	3:12 p.	Key West, Fla.	ese.	5	ne.	4	nne.	5	n.	6	nne.	9												
12	8:05 a.	Broken Arrow, Okla.	sw.	4	ese.	13	e.	12	e.	13	e.	14												
13	6:54 a.	....do	sse.	4	sse.	9	sse.	10																
	8:13 a.	Camp Knox, Ky.	w.	3	ne.	7	n.	3																
	7:46 a.	Due West, S. C.	nne.	3	ne.	4	e.	7	ene.	5														
	2:45 p.	Key West, Fla.	ese.	5	e.	4	ene.	2	ene.	5														
14	7:44 a.	Camp Benning, Ga.	wnw.	4	ene.	2	ese.	2	ese.	4	ese.	5	sse.	2	sse.	3	se.	2						
15	7:48 a.	....do	wnw.	2	se.	3	s.	2	sw.	4	sw.	2	sse.	2										
16	2:48 p.	Key West, Fla.	e.	5	ese.	5	ese.	4	se.	6	sse.	5	s.	8	ssw.	13	sw.	17	sw.	18				
17	8:01 a.	Broken Arrow, Okla.	s.	5	s.	6	sse.	7	sse.	10	sse.	14	se.	20	se.	21	se.	17	se.	14	se.	12	ese.	13
	3:33 p.	....do	ssw.	6	s.	7	s.	9	s.	9	se.	7												
	7:46 a.	Camp Benning, Ga.	nw.	5	ssw.	4	sw.	4	ssw.	3	sse.	5	se.	6	se.	9	se.	9	se.	17	se.	10		
	7:49 a.	Due West, S. C.	wnw.	3	w.	2	wsw.	4	w.	2	nnw.	4	n.	2	ese.	3	ene.	5						
18	8:08 a.	Broken Arrow, Okla.	sw.	4	ssw.	5	s.	5	se.	5	ene.	2												
19	8:18 a.	Lansing, Mich.	e.	3	ese.	5	ene.	5	e.	6	ne.	4	nne.	4	ene.	20								
	8:22 a.	Madison, Wis.	nne.	2	n.	7	nne.	5	nne.	9	nne.	11	nnw.	6										
	2:58 p.	Royal Center, Ind.	se.	2	n.	5	nne.	7																
20	8:20 a.	Camp Bragg, N. C.	ne.	4	nne.	6																		
	3.30 p.	....do	ene.	5	nne.	4																		
21	3:54 p.	Arcadia, Calif.	s.	4	ese.	4																		
	3:30 p.	Camp Bragg, N. C.	sse.	1	ese.	3	ne.	9																
	4:16 p.	March Field, Calif.	wnw.	8	e.	3	sse.	3	sse.	6	sse.	9	s.	7										
22	2:45 p.	Key West, Fla.	se.	3	wnw.	3	nw.	3	ne.	2	nnw.	3	ne.	4	n.	4	nnw.	5						
23	4:14 p.	Fort Omaha, Nebr.	n.	3	ne.	6	sw.	2	sw.	4	sw.	14												
	4:25 p.	March Field, Calif.	nw.	7	sse.	8																		
24	7:43 a.	Camp Benning, Ga.	w.	4	wsw.	1	s.	2	ssw.	4	sse.	5	sse.	3	se.	5	se.	8						
	7:46 a.	Key West, Fla.	ssw.	1	ene.	6	ene.	6																
	3:22 p.	....do	se.	2	ene.	11																		
25	7:43 a.	Camp Benning, Ga.	wnw.	3	sse.	3	ssw.	3																
	7:49 a.	Due West, S. C.	ne.	2	e.	1	ssw.	5	ssw.	6	ssw.	6	ssw.	8										
	7:59 a.	Key West, Fla.	se.	3	e.	5	ese.	6	ne.	4														
	2:43 p.	....do	sse.	3	e.	5	ene.	5	e.	5	e.	8	se.	7										



DAMAGE TO FORESTS BY HAIL IN NORTH CAROLINA.

By J. S. HOLMES, State Forester, North Carolina Geological and Economic Survey.

[Raleigh, N. C., June 30, 1921.]

On Thursday afternoon, April 28, a very heavy storm swept across northern Anson County, N. C. Hail fell over a strip extending at least 4 miles east and west, from Ansonville east to Mr. Bennett Nelme's plantation and half a mile wide. The duration of the hailstorm was said to be about three quarters of an hour, but the heaviest lasted only about 15 minutes.

The direction of the storm seemed to be from the northeast as windows on those two sides were broken, and the old paint on those sides of buildings was marked by the large hailstones. It was at the eastern limit of the storm and toward the center of the strip that the worst damage seems to have been done and the heaviest hailstones fell. At Ansonville, according to reliable witnesses, the stones were "from the size of partridge eggs to that of hen eggs," while at the Nelme plantation they were said to be as large as baseballs. Gardens were demolished, many roofs were broken up, and the grain fields destroyed throughout the belt.

Fruit trees, peach and pecan, were almost fatally injured, only the upright branches being sufficiently sound to profitably leave in the orchard. The other branches have very many places where several square inches of bark was knocked off. Few limbs which had more than 3-inch spaces uninjured were seen, when the State forester visited the area six weeks after the storm.

The country visited by this storm varies from rolling to almost level. Probably two-thirds of it is in cultivation and the other third is chiefly second-growth pine, loblolly, short-leaf and long-leaf pines mixed, but mostly loblolly. Some areas had been cut within a couple of years, leaving the smaller trees standing. On one area there were a number of old-growth long-leaf pine trees with the second growth loblolly all around. The damage to the forest seems to have been greater along the middle of the strip, gradually diminishing toward each side. In the belt of greatest damage perhaps half a mile wide and a mile long, the pines have probably less than 10 per cent of the foliage left, most of it having been beaten off, together with the twigs. The ground is still littered with twigs, needles, and cones. So far, there seems to have been no attempt on the part of the trees to put forth new shoots, but probably there has not been time enough for that. Some of the trees have already been attacked by the pine-bark beetle and there seems little power of resistance, as scarcely any gum is secreted where the insects bored into the bark. The chances are that a much smaller number of beetles to each tree will be necessary to kill them. Much pine reproduction, even second or third year seedlings, was killed by the hail, the stems often being badly bruised.

It seems certain that the owner has acted wisely in selling for immediate lumbering the merchantable timber on some 40 acres of the worst damaged forest, although he had planned to hold this for future use and further growth.

HAILSTORM NEAR BIRMINGHAM, ALA., MAY 11, 1921.

By EDGAR C. HORTON, Observer.

[Weather Bureau, Birmingham, Ala., May 30, 1921.]

One of the worst hailstorms ever known in this section of the country, and the worst that has ever come under the observation of the writer, occurred in this county on the afternoon of May 11.

The storm was apparently one of a series of hailstorms that occurred on that day from eastern Mississippi to eastern Tennessee and northern Georgia, or it was possibly only a part of one continuous storm. A very light hail of short duration fell at this station during the early morning hours, and again during the afternoon at the same hour (about 2 p. m.) as the severe hailfall in the southwestern part of the county.

The storm was variously reported as occurring from 1:10 to 2:15 p. m., and as lasting from 20 to 30 minutes where it was worst. The progressive motion of the storm would account for some of the discrepancy in the time of occurrence, although the postmasters at Johns and Sumter, in the worst affected district, reported the storm as moving at right angles to the major axis of the affected area.

There was an unbroken area of hail fall, 37 miles or more in length, and from 3 to 8 miles in width, extending from near Yolande northeastward some miles beyond the limits of Birmingham. The region of greatest hail fall was from Adger to Sumter, points respectively about 20 and 24 miles southwest of Birmingham, in the mineral district of Jefferson County.

Eyewitnesses to the storm and those that visited the district shortly after the storm had passed, reported the ground completely hidden by hailstones, even on the hillsides. In the ravines the hailstones lay one to two feet deep. Trees were so denuded of their foliage that they have been described as having the appearance of trees just budding out in spring. It is reliably reported that the roads were completely obscured by the leaves and boughs broken off by the falling hail.

Mr. John M. De Shazo, a prominent merchant of Birmingham, passed through the affected district about an hour after the hailstorm, and he reported that the air was so chilled that a dense fog surrounded him at Johns and Adger, and that his hands were so benumbed that he was very uncomfortable driving his automobile. Ice started to form on the wind shield. During this time the temperature at the station did not fall below 63°, and the highest and lowest for that day were 83° and 62°.

Some of the hailstones were still on the ground as late as the 16th, and some say the 17th, under air temperatures that never fell below 57°.

If the quantity of the hail was surprising, the size of the hailstones was phenomenal, ranging from one-half to 1 inch in diameter at the outer edge of the area to 4 inches in the middle of it. The postmaster at Johns reported the stones as being 2½ to 4 inches in diameter, and the postmaster at Sumter stated that the sizes were "from nutmeg to baseball." One hailstone was reported to have weighed a little more than half a pound. A baseball is 9 inches in circumference, and a ball of ice of that size would weigh approximately one-half pound. A conductor on the Louisville & Nashville Railroad gathered up some of the hailstones and brought them to the city, where after 22 hours in a refrigerator they were still larger than hen's eggs.

Automobile tops, where exposed to the hail, were riddled, and wood and felt roofs were badly damaged. In one instance a hailstone penetrated a roof and fell to the floor of a building. A school building belonging to the Tennessee Coal, Iron & Railroad Co., at Johns, constructed with one side almost entirely of glass, had practically every pane smashed. Other buildings were similarly damaged.

Fortunately the heaviest hail did not fall in an agricultural section, or a region where there was much live stock, but rather in the mining section of the county. Gardens were ruined, and timber suffered so that much of it may die. No deaths or serious injuries were recorded.

HAILSTORM AT WAUSAU, WIS., MAY 22, 1921.

By E. F. SIMES, Observer.

[Weather Bureau, Wausau, Wis., May 25, 1921.]

An unusually severe hail and thunder storm, visited Wausau on the evening of Sunday, May 22, 1921. It was most destructive storm that had ever been observed in Wausau.

The storm in question came up quite rapidly from the southwest, moving in a direction a little east of northeast. The center of the storm was evidently just north of the village of Knowlton, and Wausau was on the extreme northern edge; in fact, the sky was visible on the northern horizon throughout the entire storm. Thunder and vivid flashes of lightning were observed at 7:39 p. m.; at 7:53 p. m., the first rain, in the form of unusually large drops, fell with resounding smacks as they struck the pavements. At 8:03 p. m., although the rain had only amounted to a sprinkle, a sound similar to a galloping horse was heard and the first hail fell. The first hailstones were about the size of walnuts, but as the fall increased in intensity, the size of the hailstones increased until they were falling as large as oranges and apples and, in some cases, even larger than that. The hailstorm lasted 12 minutes after which a very light rain fell for about half an hour.

The belt in which hail fell extended approximately from the northern city limits of Wausau to the village of Schofield, but the area in which the unusually large hail fell seemed to be confined to Wausau only. On examination, it was found that the stones which fell at the height of the storm averaged around 3½ and 4 inches in diameter while some were reported which measured 18 inches in circumference. On being broken open they were found to be composed of six and seven layers of ice on the average. Some were found with even more layers. All of them had hard centers and most of them were roughly spherical or oblong in shape. Some stones were observed that had a kind of pincushion effect—that is, they were drawn in at the center on two sides as if they had been rotating in only one direction. The wind during the storm was very light, except for a rather strong gust at the beginning, consequently the hail came down almost straight.

It is estimated that the total damage by the storm will amount to $150,000 or more. Practically every window in the city, facing the west, was broken. A great majority of the trees were literally pruned, fruit trees suffering most by the loss of their tender branches and buds. Garden truck in general did not fare badly,

but local greenhouses were demolished and the stones beat through the broken lights, wreaking havoc among the plants and flowers within. Automobiles that were unfortunate enough to be caught in the storm as a rule received some mark signifying that fact. The large stones tore through their tops, one motorist reported twenty-one holes in his top. Wind shields were broken and wherever the hail hit the cars, the paint was knocked off and the body dented. Several people received minor injuries and bruises by being struck, but no reports were received of any serious injury.

TROPICAL STORM OF JUNE 22, 1921.

By B. BUNNEMEYER, Meteorologist.

[Weather Bureau, Houston, Tex., July 1, 1921.]

The storm was of comparatively short duration and of the milder type of hurricane. The sky was overcast throughout the day with nimbus or stratus and scud moving with the surface wind; upper clouds could not be observed.

The barometer fell until 5:40 p. m. and rose thereafter. The fall was slow with strong fluctuations until 9 a. m., then rapid, and the subsequent rise was about as fast as the preceding fall. The following barometer readings (reduced to sea-level) were taken:

	Inches.
9:40 a. m.	29.73
11 a. m.	29.87
1 p. m.	29.59
2 p. m.	29.53
3 p. m.	29.51
5:40 p. m.	29.37
6:30 p. m.	29.42

Rain fell from 2 a. m. to 9:15 a. m.; 10:50 a. m. to 1:30 p. m. and from 4:03 to 6:37 p. m., being excessively heavy between 6 and 9 a. m. when 2.77 inches fell.

Lightning and thunder were not noticed; residents about 5 miles south of Houston report faint flashes of lightning about 6:30 a. m.

The winds came in characteristic gusts throughout the day increasing in force until 5 p. m. and diminishing thereafter. The direction and force of the wind and other meteorological data are given in the table next below.

The storm moved inland over Matagorda Bay, the center passing in a northerly direction over Palacios, Wharton and Wallis, each of which reported a distinct calm, with wind coming from northwest and west after the calm.

TABLE 1.—*Wind and precipitation data for June 22, 1921.*

	A. M.												P. M.											
	1	2	3	4	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11	Mid-night.
Wind direction	NE.	NE.	NE.	NE.	NE.	NE.	NE.	NE.	NE.	E.	SE.	E.	SE.	SE.	SE.	SE.	SE.	SE.	SE.	S.	S.	S.	SW.	SW.
Wind movement	11	11	13	13	16	17	23	23	21	23	28	32	44	38	44	47	49	41	37	36	28	19	16	16
Maximum velocities and directions.	......	......	......	......	......	......	29 NE.	28 NE.	34 NE.	26 E.	42 NE.	41 E.	49 SE.	52 SE.	54 SE.	58 SE.	60 SE.	58 SE.	42 SE.	48 SE.	34 S.	......	......	......
Precipitation	......	T.	0.06	0.15	T.	0.02	1.04	0.27	1.46	0.03	0.01	0.04	0.01	T.	......	......	0.01	0.03	T.	......	......	......	......	......

METEOROLOGICAL ASPECTS OF THE NATIONAL BALLOON RACE, 1921.

C. G. ANDRUS, Observer.

[Weather Bureau, Due West, S. C., July 23, 1921.]

SYNOPSIS.

On May 21, 1921, the annual National Balloon Race started. Nine balloons were entered, and the start from Birmingham, Ala., was given the benefit of every sort of aerological advice. The several pilots were probably never before so well informed of the current and expected meteorological conditions. Acting as aide to Mr. Upson, in one of the balloons, the writer had an excellent opportunity to become intimately acquainted with the practical side of aerology in free ballooning. Air currents, true to forecasts, were light in speed throughout the race, and few opportunities for making important observations were afforded. By making utmost use of the winds of the lowest levels unaffected by surface friction, we gained advantage on the other balloons during the first night, and escaped a series of local storms of convectional origin, which forced most of the balloons to land early the 22d. The stagnation of air at all altitudes during the 22d prevented headway until after sunset, when we set out on a curved course which carried us through Kentucky, West Virginia, and to a landing place in southwest Virginia. Flying the second night was at moderate speed, low altitude above ground, and the landing was forced because no wind could be located that would increase our distance from Birmingham. While it is often the function of aerology to indicate where the highest or best directed winds prevail, in this race it was chiefly a matter of directing the escape from most unfavorable winds. Observations on the height and depth of the sea-level pressure gradient winds, their disruption by convection, and the average tendency of a free balloon to move toward decreasing pressure regions were noted. As all the other balloons were forced to land in central Tennessee by severe local thunderstorms, the victory was ours.

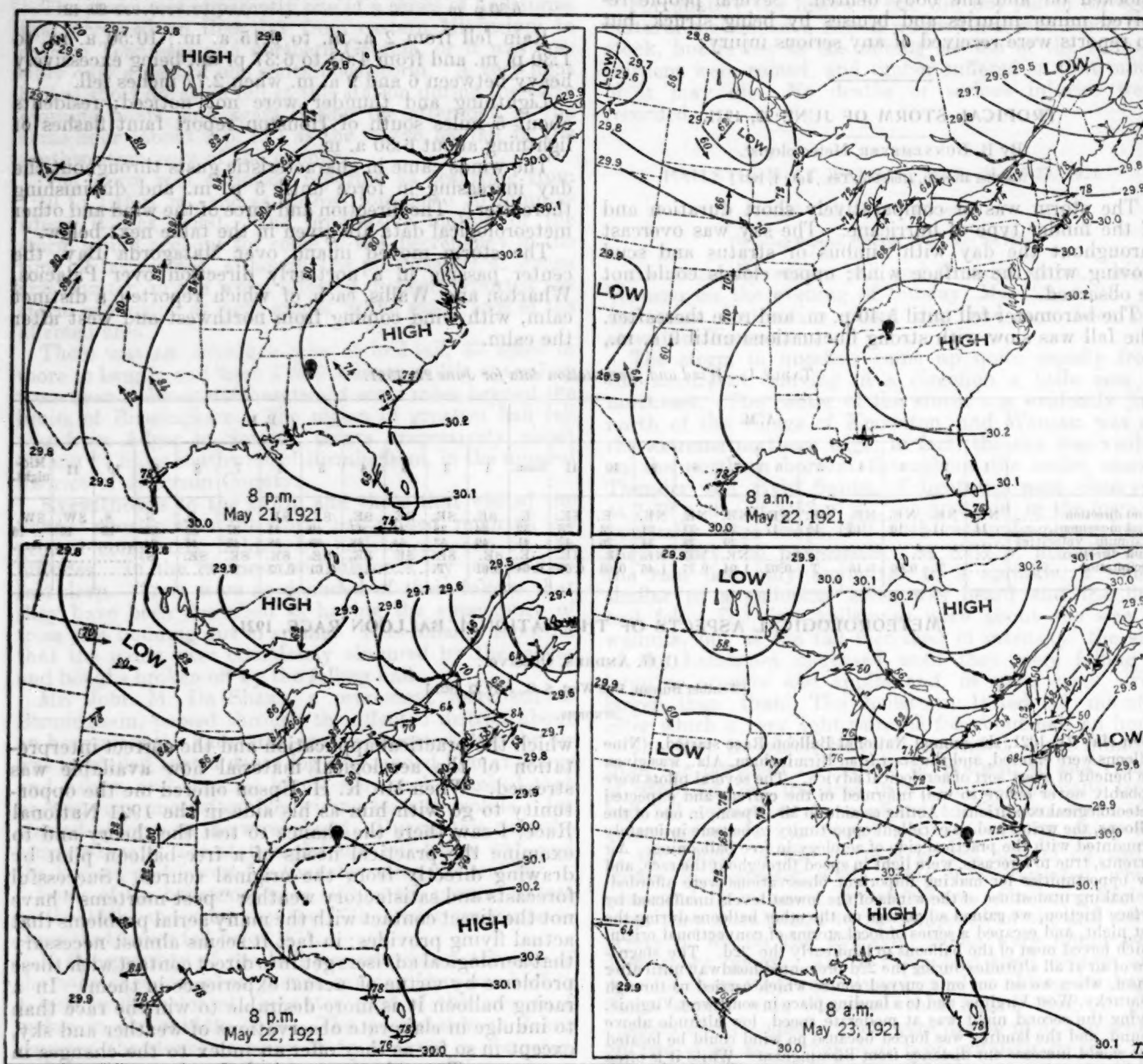
The importance of the meteorological factor in free-balloon races has been discussed in a previous paper,[1] in which the practical application and the correct interpretation of the aerological material now available was stressed. When Mr. R. H. Upson offered me the opportunity to go with him as his aide in the 1921 National Race, I saw there the chance to test the theory and to examine the practical needs of a free-balloon pilot by drawing directly from the original source. Successful forecasts and satisfactory weather "post-mortems" have not the direct contact with the many aerial problems that actual flying provides; in fact it seems almost necessary that aerological advisers get into direct contact with these problems by virtue of actual experience in them. In a racing balloon it is more desirable to win the race than to indulge in elaborate observations of weather and sky, except in so far as they offer an index to the changes in progress. To make a practical demonstration of the utility of a knowledge of meteorology rather than merely a set of observations which could be better made by means of kites and pilot balloons was the desire.

The race was scheduled to start Saturday, May 21, under rules similar to those of the 1920 International Race. As in that race, surface conditions and aerological observations were made available by the Weather Bureau from its own stations and from some aerological stations of the Army and the Navy; special forecasts for the race were issued from Washington on the 19th, 20th,

[1] Andrus, C. G.: Meteorological aspects of the International Balloon Race of 1920. MO. WEATHER REV., Jan., 1921, 49: 8-10.

and 21st; and, in addition, Messrs. W. R. Gregg and R. E. Frushour of the Weather Bureau were assigned to Birmingham for the purpose of assisting all the contestants. The aerological stations provided important data in perhaps a new way—that of showing where the least wind existed rather than the greatest.

Nine balloons started in the early evening. Conditions had been forecast and described as decidedly "slow," as away below the 1,200-meter level. Isobaric charts, typically summer ones, held but one outstanding feature, the HIGH in the southeast and over the Atlantic; the widespread flatness of gradient and temperature differences persisted throughout the race, although a small LOW energized somewhat upon reaching the New England coast from the Lake Region late Sunday night and Monday morning.



FIGS. 1-4.—Weather maps for the period of the race, showing sea-level pressure; wind direction and temperature for stations having wind velocity in excess of 10 miles per hour; and the progress of the winning balloon.

slight and variable wind-movement was the rule below the 35th parallel and at all elevations even to great altitudes. There appeared to be little chance of widespread storminess on the balloon tracks, no danger of riding out to sea, and in general conditions were neither ideal nor unfavorable; it promised to be an obstacle race. Opportunities for spectacular speed or extraordinary altitudes were not presented, but the real advantages, however indistinct, seemed to be minor variations tucked

Meteorologically, it is required to plan a course of action with consideration of these points: First, maneuvering to avoid foul weather and to remain in or get into fast and well-directed currents; second, geographic control, as in staying inland and away from the coast and dangerous topographic areas; third, ballast economy, involving the relative merits of rapid expenditure to gain great speed for a less time or careful throwing to keep in slower speeds for a greater time. In this race, the second and

third considerations were disposed of before the start, for seaward currents did not exist, and neither improvement in speed nor bettering of direction could be obtained by sailing at great altitudes. The problems simmered down to that of avoiding foul weather and finding the best winds of the low altitudes. The likelihood of cyclonic rainstorms or general convection showers was considered small, but the chances of local disturbances were considered good enough to demand the utmost speed promptly upon leaving Birmingham and throughout the first night, in order that such showers would not overtake us until we had gained sufficient distance to compare favorably with other contestants should all the balloons be forced down. The desideratum was ultimately to find our way out of the slow winds to better ones.

Birmingham was under anticyclonic control by the Bermuda southeast HIGH and wind-flow near the ground was inevitably slight. Pilot-balloon readings just before the race tell a story of weak winds, fickle currents, and energetic convection below the 2-kilometer level, and even less persistent directional drift between 2 and 10 kilometers south of latitude 35°. Further north somewhat improved speed was registered, but the balloonists could not reach this superior location. The 1-kilometer level is representative of the anticyclonic character of the wind drift, with the centers of outflowing streams respectively over eastern Virginia at 4 p. m., 21st; over North Carolina at 8 a. m., 22d; over South Carolina that afternoon, and in upper Alabama at 8 a. m., 23d. The entire problem for both forecaster and balloonist was bound up in the behavior of this HIGH. Temperature similarity and radiation equality over many degrees of latitude expressed themselves dynamically in the wiping out of wind flow at great altitudes.

The race thus became a search for the quickest way out of the HIGH. Reports indicated conspicuously that the currents of greatest strength and constancy within 500 miles of the start were toward the north and actuated by the near-ground pressure gradient. The optimum level was reckoned to be that altitude below which wind flow was less than gradient force owing to surface friction and topographic damping and above which wind flow was diminished progressively aloft as pressure gradients weakened in the free air; theory and observation agree that this level occurs at about 500 meters over the surface, and usually lower by night than by day. This promised to be a useful layer throughout the race, for it would be here that wind would develop as promptly and as favorably as at any other, whether the control were cyclonic or anticyclonic. In the event of encountering local storms, it was proposed to go to great lengths to keep out of the condensation area, since the ballast expense in this region of varying densities, vertical discontinuous currents, and precipitation may be as large as that required to navigate safely above the entire storm. These storms possess enough individuality to require a specific solution in navigating for each case, and the complete downfall of most of the other balloons in violent storms points to the sudden and fierce sort of local disturbance that is particularly menacing to balloonists.

Two balloons had already made their "get-aways" into the northwest when our balloon was borne across the field by the tugging of willing hands. The final weighing off, the last farewells, and the starter's greeting "Are you ready?" are thrilling affairs, but nothing can compare with the overwhelming sense of relief and joy at the first upward move. Ballast had been somewhat generously dealt at the start and we made a prompt swing upward to an altitude of 400 meters. Occupied by the cares of disorderly equipment and the wonderful novelty of this, my first free-balloon ride, the first hour slipped by rapidly. We had risen from the field at 7:57 p. m., and by 8:30 (ninetieth meridian time) had commenced the search for the optimum level. It was easily located by a series of soundings which indicated its presence between 450 and 500 meters altitude. The balloon had attained good equilibrium, the prospect was for smooth sailing, and Mr. Upson curled up and gained some three hours' sleep. Novel impressions were being made on all my senses, fair moonlight illuminated in faint but distinct fashion the various types of terrain we floated above, and varied sounds from field and woodland a half mile below were clearly audible. I distinguished plainly the croaking of frogs, the keener notes of the cricket and the barking of canine watchkeepers. Thin fog rested on the ground in places, probably hollow, while, above, a large sheet of alto-cumulus shaded the moon, and off to the west and north a row of castellated clouds rested on the horizon. A barn afire in the distance belched upward a cloud of smoke which rose at first quite vertically, then was flattened off by the currents above the ground. We now found our altitude increasing somewhat in our maintenance of the optimum level, partly because of greater height of the land above sea level. The sailing was luxuriously peaceful, and at 2 a. m. I took my turn at a three-hour nap.

It was during Mr. Upson's watch, during the last night hours, that the only occasion of sighting one of the other balloons occurred. This balloon was sighted above us, evidently in a slower current. It descended behind us, apparently searching for that current which we had run ahead in, but it descended too far, so that it was soon lost in the distance to the rear. When sunrise came and our balloon responded to the radiation, there was brought to a close a practically constant-altitude flight of about eight hours, at a level at which the actual wind closely approximated the gradient wind for sea-level pressure,[2] both in direction and speed. Other balloon runs have been undertaken intentionally for constant-altitude flying[3] but upon this particular occasion the constant altitude was maintained not by the use of valve and ballast to any extent after once attaining the proper level, but rather by the free motion of the balloon; and we may safely conclude that the path of the balloon closely resembled that of a particle of air starting with us at 8:30 p. m. The path is a smooth curve almost coincident with the isobar of 30.2 inches sea level at both 8 p. m., 21st, and 8 a. m., 22d., and indicates an average speed of about 8 m/s. The layer of optimum wind was 150 meters thick, between 600 and 750 meters sea-level altitude; above it the wind held the same direction but fell off, and below it the wind backed somewhat and fell off.

To make the most of the first night it was important that we have faith that an optimum layer existed, that we prove its presence and maintain our position within it. Aerology gave us confidence in the existence of the layer, and constant attention and speed soundings produced the desired results. At least one other balloon had twice been through the layer but had failed to stay there, and it was within easy reach of all. We now know it was the biggest opportunity of the race, though not apparently a striking one at the time. But we did try to use it to the fullest. Then and there the race was won.

[2] The sea-level gradient here referred to is the gradient as it appears on a map of station pressure reduced to sea level. The wind between 500 and 1,000 meters above the surface usually corresponds closely to this gradient. It should be remembered that this is true only where the elevation of the surface above sea level is not great.—EDITOR.

[3] Meisinger, C. LeRoy: Constant-elevation free-balloon flights from Fort Omaha. MO. WEATHER REV., Aug., 1919, 47: 535-538.

Night flying, when normally smooth, is delightful in its steadiness and equilibrium. But sunrise magically changes this, and the identically ripe conditions for smooth sailing at night are likewise and proportionally favorable for disturbed and convection-harassed sailing by day. At 8 a. m., Sunday this convection had so cut up the horizontal wind flow that we could find little more than half the speed we had held all night. The vertical currents had distributed the 150-meter optimum layer of the night over a layer perhaps more than 3,000 meters thick, all of whose parts possessed only the average of the entire layer. Free balloons tend to continue or augment vertical motion imparted to them, on account of momentum, a continuation of the contraction or expansion of the gas, and the usual persistence of the vertical components of the air surrounding the balloon; thus the effect of convection is telling on the supply of ballast. There is also much difference in a day's convection. That of the early morning is vigorous, but it is of smaller magnitude than that of the later hours. In the early morning it is merely a series of jets and spurts of warmed air; these grow in extent, strength, height, and speed until by mid-afternoon they become the great pillars for cumulus and cumulo-nimbus clouds.

Shortly after daybreak, a bank of "threatening and rainy clouds to the northwest" (to quote our log) indicated inclination toward local storms, and we then decided to stay as low as economically possible in respect to ballast. The bank moved slowly southward and we moved northeastward, so that we gradually drew away from it. It is altogether likely that this storm was the one which enveloped the other balloons, behind and to the west of us, and caused their descent, on account of violent convectional winds. Investigation of the currents aloft showed neither steady currents of strength nor favorable direction at high altitudes, and by midday we were meandering slowly eastward; by 3 p. m. below us rose the foothills of the wooded mountains of eastern Tennessee. This was a trying period. We dodged around cumuli, were borne up and down, but always without a break in the stagnation of wind. The best promise that I could make Mr. Upson was that nightfall should restore to us the gradient winds of the previous night, and that if the few cirri which had spread upward out of the northwestern sky were trustworthy the wind might be even stronger than on the previous evening.

And just before 4 p. m., far off to the east, smoke was discovered drifting slowly toward a northerly point. And then springing up from nowhere two small rows of strato-cumuli rolled along the hilltops also in a northerly direction and far below us. It was disconcerting that this favorable breeze should spring up so far beneath us, for we were shortly to undergo the usual contraction of gas due to sunset, with the accompanying loss of buoyancy and altitude, and we faced the question of expending gas at the time, and a corresponding weight of ballast later to overcome the natural contraction of the balloon, or waiting for the nocturnal contraction and wasting that lower breeze. Another trying period was endured, while we waited, hopefully extravagant of that wind far below in order to save ballast for the night. Temporarily shaded by horizon-clouds, we made two descents to near ground, only to rise again when the sun once more shone upon the envelope; thus we oscillated between 600 and 2,400 meters altitude from 4 to 6 p. m. The best current, 6 meters per second from south-southeast, was found about 150 meters above ground; this diminished and veered steadily up to about 1,100 meters where it was 3 meters per second from west-northwest; above that level direction was constant and a slight increase in speed prevailed. By 8 p. m. contraction of the gas bag had been practically completed, and we again made plans to stay within the sea-level gradient winds the second night.

Stability became well pronounced before midnight; evidence of it could be observed on the ground where fog in great white lakes filled every valley and glistened like snow in the moonlight. Occasionally a wreath of fog would be whisked off the upper surface and be carried along by the wind to dissolve soon in wind-blown threads, and it was evident that the surface wind failed to penetrate into these hollows where air-drainage alone could produce the thick fogs observed. This smoothing of ground contours by the wind is well marked, and surprising in its force, for upon approaching the first mountain that towered above us an impulse to expend ballast was apparently correct but we soon found ourselves to have ascended far above the mountain, and we then learned that we could trust the wind flow across the hills to carry us over their tops and down their leeward sides. It was my impression that the speed was increased on the windward sides and decreased on the leeward but the perspective effect of nearing and withdrawing ground may have been partly responsible for this effect. We skimmed the hills all night.

During this night we described an arc of a circle about 200 miles in radius drawn around a center east and north of Birmingham and eventually such a procedure would result in our arrival at a point whence we would commence to backtrack toward our starting point. Sunrise came when we were crossing the main ridges of the Appalachians, 1,200 meters in altitude; our speed was now the highest of the voyage, over 11 meters per second from northwest, but our distance from Birmingham was being bettered but slightly. Finally, we crossed the last range of hills, the Blue Ridge, with lower levels of land visible beyond, but to our dismay we found our direction now veering still farther, so that we moved on the circumference of a circle centered upon Birmingham, temporarily anyway, with every prospect of incurving at any moment. A field was selected close within the "shadow of the hills," in the belief that the wind would be shut out there by the hills and an easy landing would be possible, but our plans were suddenly disrupted by a large cumulus which had built up around us and tossed us up like a bubble to 1,600 meters altitude. Our descent from here to the ground at about 500 meters was so gentle we hardly knew when we reached the surface.

Naturally we had not landed without deliberating on the feasibility of trying the wind at great altitudes, but from observations of the cirrus clouds and by an excursion to 2,600 meters, we were convinced that the wind veered even more unfavorably the further aloft we might go, and we could not consider yielding any of the precious miles from Birmingham. Our deliberations over the gain or loss of a single mile seem rather comic now, for we might have landed 20 hours earlier and still taken the first place, but such is balloon racing's creed: never lose a mile nor fail to gain one.

Our landing was an unusual one in some respects. It was gentle and easy, was effected with the valve only, and was made with full equipment and even ballast aboard, for it was forced not because of the usual circumstances of ballast exhaustion and foul weather or open sea, but by the malevolent direction of the wind

which we could then neither escape nor improve. The barometric situation appeared to be that of a deepened LOW (perhaps the rehabilitated northwest LOW) passing out to sea, with high pressure following eastward behind it, and such a situation promised no improvement in the wind direction for several hours, so that a struggle for time seemed impractical. The actual weather map does not quite agree with the hypothetical one, but the wind reports show that we could have gained nothing by remaining aloft and might have lost some distance. We had been aloft over 34 hours and were the only team to go through the second night.

The balloon voyage itself provides two important observations. One is the height of the ceiling of the wind produced by sea-level isobars. Each night we flew near this ceiling, and we may conclude that when stagnation occurs aloft the wind will tend to increase with altitude up to this ceiling where friction is at a minimum and thence upward will decrease as pressure gradients diminish. It is gratifying to note that the sea-level gradient wind, agrees closely with the actual wind observed at the expected altitude above ground (about 500 to 700 meters), both in direction and speed. Another observation is the tendency, which I have found exhibited in other balloon flights, for a balloon to land at a point where pressure is slightly lower than at the start of the balloon (with correction for altitude). On our voyage, the average rate at which we crossed isobars of decreasing pressure was 0.005 inch per hour.

It is appropriate to add that the position of meteorological observer in a racing balloon is exacting and constantly fraught with perplexities over weather and wind, yet the exhilaration and serenity of quiet air travel is so delightful and the unfolding of meteorological processes is so interesting that the net result is a keen joy in the game. Upon landing, one is overwhelmed with three fierce desires: to learn where the other balloons landed, to see a weather map and hold a "post-mortem" on your own flight, and to sleep.

While good luck, complete and reliable equipment, and plenty of courageous endurance are always necessary ingredients in a recipe for winning balloon races, it will be one of the most satisfying results of the race if it's outcome has proved that in addition to these ingredients, meteorology, providing reliable data of current conditions and future prospects, correct assumptions as a basis for operating tactics, and capable interpretations of weather processes as they unfold, has taken a higher place on the list of the necessities of the balloonist.

A study of the stormy conditions reported by the other balloonists indicates that the disturbances into which they were drawn were confined to a small area, and were of the class of local convectional showers, which may exhibit over a small area all the violence of the fiercest storms. No showers were reported in the southeast on Sunday, except in Florida and in the vicinity of Nashville, Tenn., where the balloons were forced to descend. It may be possible that the surface relief was in some measure responsible for the formation of thunderstorms in the more level land around the river valleys than in the hilly regions of the eastern part of the State, although it was our experience even there that cumuli seemed to assume huge proportions. Unfortunately there was no strong alternate wind at high altitude to which escape might have been had, but there seems to have been a slow current in those upper regions which, if attainable in ample time, should have carried the balloons to a safe distance from the storm even if toward Birmingham, and from this place the voyage might have been resumed and continued into the second night. The logs of the other balloons show unmistakeably that a hard fight was made to outride the storm; and we may again conclude that well-defined local disturbances and thunderstorms must be respected by all travelers in the air.

EFFECT OF CHANGE IN THE POSITION OF THE THERMOMETER SHELTER AT ESCONDIDO, CALIFORNIA, UPON THE MINIMUM TEMPERATURE.

By HENRY F. ALCIATORE, Meteorologist.

[Weather Bureau, San Diego, Calif., Apr. 17, 1921.]

SYNOPSIS.

An analysis of minimum temperature readings taken at Escondido, Calif., both before and after the instrument was moved to higher ground showed that an increase of elevation of 20 feet raised the minimum temperatures considerably in respect to mild mornings during November and February, and on all mornings during December and January. Also that the effect was more pronounced for temperatures ranging from 33° to 38° than for the limits between 30° and 33°.

In October, 1919, the instrument shelter of the special meteorological station at Escondido, Calif., was moved from the old site at the end of the Hubbard lemon orchard to another point in the same orchard about 408 feet north and 72 feet west of the old site, and 20 feet higher, at the suggestion of the chamber of commerce with a view to obtaining temperature records representative of a larger portion of the citrus belt centered about Escondido.

Now, did the change affect the minimum temperatures recorded after October, 1919? If "yes," to what extent and in what way? Is the science of climatology likely to be benefited by such a practice? Tentative answers to these questions will be found in what follows.

The data used were the daily minimum temperatures at Escondido, and El Cajon, for three seasons before the change and the two seasons next following. The elevations of the stations named are, 742 and 482 feet, respectively, above sea level, and separated from each other by a distance of about 15 miles in an air line.

As a basis of comparisons we chose the El Cajon temperature record. All the minima recorded at that place (below 40°) were tabulated in groups differing from each other by 1°, and the corresponding, simultaneous minima of the other station were entered oppositely thereto. The mean variations from the base-station temperatures were computed for each degree of temperature (39, 38, 37, etc.), and tabulated by months as indicated in Table 2. (The Bonita and San Diego records were used as checks on the work.) The values in Table 2 were then plotted in the manner shown in the graphs (not reproduced).

A glance at the Escondido graph shows that the coldness or mildness of the mornings at the base station is a function of the variations of the Escondido minima; also, that while some were plus and some minus before the shelter was moved, all the variations after the change were of one order, i. e., plus. On the other hand, the curves in the Bonita and San Diego graphs, do not show any marked positive or negative departures from the base-station minima, as might have been anticipated inasmuch as the shelter at Escondido was the only one of the four whose position was altered.

The tabulation of the net changes in temperature due solely to the moving of the shelter at Escondido (Table 1) shows very large changes on *mild* mornings (minima of 38 to 33), but very small ones on *cold* mornings (minima of 32 or lower) during November and February. The changes were *large*, however, on both types of mornings during December and January.

Passing from frost temperatures to milder ones, a statement of monthly mean minimum temperatures was prepared (Table 2) which shows a general agreement as to signs. Escondido after the change being uniformly higher than El Cajon. Considering the total number of minimum temperatures recorded the net effect of the change in the position of the thermometer shelter at Escondido appears to be an increase in the minimum temperature at that station of 2.5° F. on the average.

Summarizing results we found that the principal effect of changing the position of the Escondido shelter has been to raise the minimum temperatures, on mild mornings, 3.6° in November, 3.7° in December, 4.2° in January, 4.1° in February; on cold mornings, 0.7° in November, 4.5° in December, 3.8° in January, 0.3° in February.

TABLE 1.—*Apparent net changes in minimum temperatures at Escondido due to moving the instrument shelter to higher ground.*

Month.	Temperature limits.	Net changes.
	°F.	°F.
November	38-33	+3.6
	32-30	+0.7
February	38-33	+4.1
	32-28	+0.3
December	38-33	+3.7
	32-26	+4.5
January	38-33	+4.2
	32-26	+3.8

TABLE 2.—*Comparative monthly mean minimum temperature, El Cajon and Escondido, Calif.*

Before.				After.			
Year.	Month.	El Cajon.	Escondido.	Year.	Month.	El Cajon.	Escondido.
		°F.	°F.			°F.	°F.
1916	November	37	38	1919	November	41	42
1917	do	42	42	1920	do	40	42
1918	do	43	42				
1916	December	35	34	1919	December	38	40
1917	do	36	36	1920	do	36	38
1918	do	37	36				
1916	January	42	40	1919	January	40	42
1917	do	38	35	1920	do	37	39
1918	do	36	36				
1916	February	44	42	1919	February	44	43
1917	do	39	37	1920	do	37	39
1918	do	41	40				
Mean		39.2	38.2			39.1	40.6
Difference			−1.0				+1.5

CONVECTION-DOME HYPOTHESIS OF ORIGIN OF CYCLONES.

By GRIFFITH TAYLOR.

[Excerpts reprinted from "Australian Meteorology, a textbook including sections on aviation and climatology" (Clarendon Press, Oxford, England, 1920), chapter 18, "The origin of the tropical lows in Australia," pp. 172-188, figs. 133-152.]

"The 'convection dome' hypothesis, as I may term it, assumes that a fluid flowing around an obstacle (the convection dome) is built up in our troposphere, and that most of the tropical eddies in Australia originate there. The clear skies often associated with the dome show that it is not constituted quite like temperate lows. The isobars and isohyets strongly support this hypothesis.

[This hypothesis of the origin of cyclones might be called convecto-dynamic since it is intermediate between the convectional and dynamic theories. The old convectional theory is that cyclones originate because of the low-pressure area caused by warmer air in it than that in an anticyclone. Hann definitely overthrew this convectional theory so far as European conditions are concerned by proving that above 1 or 2 kilometers the air in cyclones is colder than in anticyclones.[1] While this proved that European cyclones were not *maintained* by the low pressure owing to the lighter air, it did not prove that cyclones did not *originate* from low pressure produced by convection over a warm area. Once an eddy is established there is no reason why it should maintain all of its original characteristics. Its temperature at any part of its course would be determined by that of the air entering the whirl (and modified by changes of pressure or the physical condition of the water content); and so long as the eddy is driven or maintained, say, by differences in temperature at the same level, its degree of internal temperature is prescribed by the cooling due to the forced ascent of the air, and thus its temperatures in intermediate and upper levels are lower than those at corresponding levels in anticyclones.

Dr. Taylor shows that 80 per cent of the summer tropical lows of Australia are formed by budding off from the two semipermanent areas of heat low pressure.—*C. F. B.*]

"*Mechanism of the lows.*—In figure 152, I show in a generalized fashion what I believe to be the mechanism of many of our tropical LOWS in summer. The sun is heating northern Australia and a convection dome is built up, reaching into the westerly and northwesterly drift as shown. This causes the formation of eddies from time to time in the upper air which sail away to the southeast. They do not always extend down to the surface, possibly being at times obstructed by the trade-wind belt.

If the conditions are favorable they may supply rain with loop isobars at the surface (see fig. 150). They may increase in intensity and form a definite cyclonic low as in figure 151.

"*Summary.*—The distribution of permanent winds, of cyclones, anticyclones, and calms is always in a state of flux. Nature makes a compromise from day to day between the various dynamic and thermal controls. The writer believes that the regions of greatest convection (the convection domes) are logically more likely to control the supply of LOWS and of rainfall and storms than the so-called "centers of action" (permanent HIGHS). The latter are the stagnant portions of the atmosphere—the Sargasso Seas of the ocean of air. Here are those regions where convection is least operative and which nature accordingly uses as her "sinks." They, too, may, however, act as more or less stable obstacles in the belts of high pressure.

"It is easy to trace the "budding off" of HIGHS from the center of action in the north Atlantic. Every few days an independent anticyclone appears to split away and travel across to France or Spain. It can apparently be traced around the world, merging in the other centers of action as it arrives in their domain, and then traveling on again.

"To sum up, I feel sure than until the semipermanent HIGHS and LOWS are explored at least as fully as has been the case with the traveling eddies of temperate climes, it will be unwise to neglect convection as a very vital factor in our world circulation."

[1] See pp. 103-128 in vol. 2, of "*Les bases de la Météorologie historique—état de nos connaissances,*" by H. H. Hildebrandsson and L. Teisserenc de Bort, Paris, 1900.

THE MASS OF THE ATMOSPHERE AND OF EACH OF ITS MORE IMPORTANT CONSTITUENTS.

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., June 18, 1921.]

It is worth while, perhaps, to compute the approximate mass of the atmosphere and of each of its more important constituents. An exact calculation of these masses is not possible from the limited data we now have.[1] However, since but little gas of any kind extends beyond the 100-kilometer level, as we know from auroral and meteoric phenomena, it seems that both rotational and decrease-of-gravity effects must be small, and that the following computed minimum possible values are close to the exact values.

Total mass of the atmosphere.—The total mass A of the atmosphere, in grams, is given approximately by the continued product of the world average height of the mercurial barometer, in centimeters, at the actual surface of the earth; the density of mercury; and the area of the earth in square centimeters. These several values are: Average height of the barometer,[2] at normal gravity and 0° C., 73.7 cm.; density of mercury at 0° C., 13.5951; area of the earth, 51 by 10^{17} cm.[2] Hence

$$A = 73.7 \times 13.5951 \times 51 \times 10^{17} \text{ grams,}$$
$$= 511 \times 10^{16} \text{ kilograms.}$$

Water vapor.—Assuming the distribution of humidity given by Arrhenius[3] to be substantially correct, and substituting his values in Hann's equation[4] for the total water vapor W in the atmosphere, it appears that, on the average, this vapor is the equivalent of a water layer 2.6 centimeters deep covering the entire earth. Hence, closely,

$$W = 2.6 \times 51 \times 10^{17} \text{ grams,}$$
$$= 1326 \times 10^{13} \text{ kilograms.}$$

Permanent constituents of the atmosphere.—To find the approximate amounts of the permanent gaseous constituents of the atmosphere, assume: (*a*) That the percentages of these several gases are constant, in the absence of water vapor, throughout the troposphere; (*b*) that in the stratosphere these gases are distributed each as though it alone were present. These assumptions are based on the facts that vertical convection, effective as a mixing agent, is active in the troposphere and absent in the stratosphere.

[1] Jeans, *The Dynamical Theory of Gases*, ch. xv; Woodward, *Bull. Amer. Math. Soc.*, 1900, 6: 143.
[2] Hann, *Lehrbuch der Meteorologie*, 3d edition, p. 182.
[3] *Phil. Mag.*, 1896, 41: 264; Hann, *Lehrbuch der Meteorologie*, 3d edition, p. 235.
[4] *Lehrbuch der Meteorologie*, 3d edition, p. 231.

Hence the total mass M of any one of the permanent gases of the atmosphere is given approximately by the equation

$$M = \underbrace{(1-k)(A-W)Vm'/m}_{\text{Troposphere.}} + \underbrace{k(A-W)V}_{\text{Stratosphere.}} \qquad (1)$$

in which k is the fraction of the whole atmosphere, exclusive of the water vapor, in the stratosphere; A the total mass of the atmosphere; W the total amount of water vapor in the atmosphere; V the volume per cent of the gas in question in dry air; m' the molecular weight of this gas; and m the virtual molecular weight of dry air.

According to Ramsay[5] and other good authorities, the volume percentages of the constituents of dry air, and their respective molecular weights, are:

Nitrogen	78.03	28.02
Oxygen	20.99	32.00
Argon	.94	39.88
Carbon dioxide	.03	44.00
Hydrogen	[6] .01	2.02
Neon	0.00123	20.0
Helium	.004	4.00
Krypton	.00005	82.9
Xenon	.000006	130.2
Dry air		[7] 28.97

Since the height of the troposphere varies with latitude, it follows that the percentage of the total air in the troposphere over any given place also is a function of latitude, as it is likewise of season and of weather conditions. However, from what is known of the upper air we may assume, as a fair approximation, that the world-wide average height of the barometer at the base of the stratosphere is 145 mm.

Substituting the proper values in (1) we have, for nitrogen,

$$M_n = \left(1 - \frac{145}{735}\right)\left(511 \times 10^{16} - 1326 \times 10^{13}\right)\left(\frac{78.03}{100}\right) \times \frac{28.02}{28.97}$$
$$+ \frac{145}{735}\left(511 \times 10^{16} - 1326 \times 10^{13}\right)\left(\frac{78.03}{100}\right) = 38722986 \times 10^{11}$$

kilograms.

Similarly for the other gases, varying, accordingly, the values of only V and m'.

Hence the total masses of the atmosphere and of its several constituents are, approximately—

	Kilograms.
Atmosphere	511×10^{16}
Nitrogen	38722986×10^{11}
Oxygen	11596239×10^{11}
Argon	623925×10^{11}
Water vapor	132600×10^{11}
Carbon dioxide	21658×10^{11}
Hydrogen	1291×10^{11}
Neon	471×10^{11}
Krypton	64×10^{11}
Helium	63×10^{11}
Xenon	11.6×10^{11}

[5] *Proc. Roy. Soc.*, 1908, 80: 599.
[6] This value is given in the *Recueil de Constants Physiques*, and is accepted by Hann. Some authorities, however, give much smaller values.
[7] Virtual, or weighted average, molecular weight.

ALTITUDES OF THE BASES OF LOWER CLOUDS AS DETERMINED FROM KITE AND BALLOON OBSERVATIONS.[1]

By OLLIE LEE LEWIS, Meteorologist.

[Weather Bureau, Washington, D. C., June, 1920.]

SYNOPSIS.

The altitudes at which kites and pilot balloons disappeared into bases of clouds on [illegible] occasions at United States Weather Bureau stations in the United States east of the Rocky Mountains are plotted in the form of frequency diagrams. When grouped together without regard to the name given by the observer, these observations show but one altitude of maximum frequency, [illegible] 350 to 400 meters above the ground, the same as for stratus clouds. The bases of strato-cumulus were most frequently at [illegible] to [illegible] meters above the ground; and those of cumulus between 1,000 and 1,700 meters. No difference was found between the northern and the southern groups of stations.—*C. F. B.*

It is primarily the purpose of this paper to present graphically, with a brief discussion, the results of some special studies made by the writer on the altitudes of maximum frequency of cloud bases, as determined largely from kite flights and pilot balloon ascensions.

LEVELS OF MAXIMUM AND MINIMUM CLOUDINESS.

According to the international system of cloud classification, and from a great many measurements of the heights of the different forms, certain average and limiting heights of each type have been found,[2] and these average altitudes have been grouped into five levels of maximum cloudiness. H. H. Clayton,[3] in his studies of cloud heights at Blue Hill Observatory, gives the following as average altitudes for these five levels: Stratus, 500 meters; cumulus, 1,600 meters; alto-cumulus, 3,800 meters; cirro-cumulus, 6,600 meters; cirrus, 8,900 meters. Nimbus is included with the stratus, strato-cumulus with the cumulus, strato-cumulus with the alto-cumulus, cumulo-nimbus base with cumulus and top with cirrus, and cirro-stratus with cirro-cumulus and cirrus.

Humphreys[4] states that "When the frequency of clouds is tabulated with reference to elevation, maxima and minima are found with the layers to which they obtain growing thicker with decrease of latitude." In the same work he discusses five principal levels of maximum cloudiness together with the four intervening regions and the isothermal region beyond, of minimum condensation.

These levels of maximum condensation are fog level, from the surface to an altitude of seldom more than 100 to 200 meters; cumulus level, foul weather type, commonly 1 to 2 kilometers above the surface; cumulus level, fair weather type [alto-cumulus] 3.5 to 4 kilometers above the surface; cirro-stratus level, at about 8 kilometers; and the cirrus level, average elevation in middle latitudes about 10 kilometers.

Regions of minimum condensation are scud region, between the fog level and the lower or foul weather cumulus level; the intercumulus region, from 2.5 to 3.5 kilometers; the alto-stratus region, from 4.5 to 6.0 kilometers; the intercirrus region, from 8.5 to 9.5 kilometers; and the isothermal region, beyond an altitude of about 11 kilometers in middle latitudes.

CLOUD DEPTH OR THICKNESS.

While there have been a great many measurements of cloud heights by various methods, the greater portion of such measurements have been to determine the height of the cloud base. While it is known that the thickness of clouds varies from the 8 or 10 kilometers of the most towering cumulo-nimbus, usually associated with a violent hail storm, down to that of a vanishingly thin cirrus, systematic measurements of cloud thickness have not been numerous, owing to the difficulty with existing methods.

Although the ideal conditions of no vertical air currents probably seldom obtain, it is believed that in temperate latitudes during all seasons, except the hottest hours during summer days when excessive local heating over land surfaces gives rise to strong vertical circulation, the vertical components of the atmospheric circulation will be relatively small in comparison with its general horizontal components; and, under such average conditions the foregoing ascensional rate formula may be generally depended upon to give values to an accuracy of about 5 per cent.

Unfortunately, for the present study, vertical currents usually do accompany clouds of all types, and are predominant in connection with the cumulus type. This will give rise to strong local convectional circulation, which is liable to introduce very large errors when the ascensional rate formula is used in calculating altitudes of such clouds from single theodolite observations on pilot balloons. On the average, however, from a long series of observations, the mean values so deduced for altitudes free from strong vertical currents must be somewhere near the actual values.

Altitudes from the disappearance of kites.—Of the two general methods for determining altitudes by means of kite flights, only the method of simultaneous theodolite readings of the angular altitude of the kite and the length of wire out at the moment of its disappearance in cloud base is used in actual computations, according to the equation, $H = s\ (\sin\ \phi)$, where H represents the cloud height, s the length of wire out, and ϕ the angular altitude of the kite. From this computed value of H, which is theoretically too high, 2 per cent is deducted.

The "hypsometric" formula could be used by observing carefully the exact moment at which the cloud disappears and computing the pressure and its corresponding altitude at a point on the pressure trace on the kite meteorograph sheet corresponding exactly to the same time. But since it frequently happens that an error of a minute or more is introduced in the clock time-rate, it follows that the general accuracy of the results obtained in this way would be no greater, but probably less, than that attained by the other method hereinbefore discussed.

Altitudes from the disappearance of pilot balloons.—By means of the "ascensional-rate" formula,[5] $r = 71\left(\frac{l^3}{L^2}\right)^{.208}$ where r represents ascensional rate in meters per minute, l the free lift, and L the total lift, the altitude can readily be determined directly from the formula, or from curves and tables made up from this formula. The product of the ascensional rate thus obtained and the minutes elapsing between the time of the balloon's release and that of its disappearance in the cloud base gives the altitude of the cloud base in meters. As previously explained, the accuracy attained by single theodolite observations of pilot balloons and computations thereof

[1] Presented before the American Meteorological Society, Washington, D. C., Apr. 22, 1920.
[2] See table reprinted in Mo. WEATHER REV., Sept., 1920, 48: 514.
[3] Discussion of the cloud obsrevations. *Ann. Astr. Obs. Harvard Coll.* 1896, vol. 30, pt. 4, pp. 271–500, 18 plates. Ref. to p. 341.
[4] Physics of the air. *Jour. Franklin Inst.*, 1918, pp. 613–646.
[5] Cf. Mo. WEATHER REV., Apr., 1919, 47: 210–225, and Dec., 1920, 48: 692–697.

from the ascensional-rate formula is not considered nearly so great as that from kite observations. It must be remembered, however, in using a computed rate of ascent for pilot-balloon altitudes that there must be no vertical component to the atmospheric currents through which the balloon passes, and that for the formula used in the United States,[5] the balloon must be of the 6 or 9 inch spherical type.

DISCUSSION AND INTERPRETATION OF DATA.

A collection and systematic study of over 6,000 individual measurements of the altitudes of cloud bases from such kite and balloon observations as were obtainable at seven kite aerological stations and over twenty pilot-balloon stations located in various latitudes and longitudes throughout the United States east of the Rockies, some of short record and other extending over a period of more than five years, thus representing all seasons and all the varying conditions of wind, etc., have been made by the writer, and the results of such study are presented graphically in figures 1 to 8, inclusive, in this article.

In the scheme followed in plotting these data, the ordinates represent altitudes of the cloud bases and the abscissas represent the frequency, or number, of cloud bases observed at each altitude. It may be remarked that the altitudes can be accurately represented only to the nearest 50 meters. But this perhaps is a trifling discrepancy as compared with possible errors due to the best methods of measurement now in vogue, since it often happens that a kite or balloon is observed for some time after it actually reaches the lower portions of the cloud before it completely vanishes from sight. This would of course introduce an additional error. From a great many observations, however, during all conditions of weather that would permit such observations, it is quite probable that many of those irregular errors would balance one another in the long run, and the summation of the final results of such observations would be fairly representative of average conditions.

Various schemes of grouping these data have been adopted, some in accordance with long established principles of grouping according to special types of clouds, seasons, and latitudes; while, again, other methods have been adopted quite different from the customary treatment of such data. But the primary object of all these studies is to ascertain whether several regions, or levels, of maximum and of minimum cloud frequency, or condensation, really *do* exist, as usually accepted, or *do not* exist, as contended in 1918 by C. F. Brooks from unpublished observations made in Texas;[6] and, if so, how many such distinctive levels there are, and what their average altitudes are. With this object in view some of the accompanying cloud charts were made by combining certain typical forms and omitting others, while others were made by utterly disregarding forms or types and charting all cloud forms together. The one shows in a general way whether there exist levels of maximum frequency for each particular group, and, if so, the average altitude of each; the other shows whether there be actual regions of maximum frequency of condensation, or cloud formation, for all forms regardless of type. This latter method appeals to the writer as the most logical one to determine whether there are in reality such regions of maximum and minimum frequency of condensation as have been assumed; for, if there be such regions, it is obvious, as the terms suggest, that all "condensations," regardless of the name given to the cloud formed, must be given equal weight. If we fail to give equal weight to all types, then we are not finding the regions of maximum or of minimum frequency of condensation in general, but merely the levels of maximum frequency for each particular cloud type under consideration. It is quite evident, therefore, that with any principle of cloud classification according to *form* and *altitude* we should expect to find certain levels of maximum frequency corresponding to the mean altitude obtained for each type or group; e. g., if we divide the number twelve into four successive parts of three units each and let these represent certain cloud forms classified according to altitude, we should very logically expect to find four separate values, each representing the mean of all the observed altitudes within their respective zones, and these average values would then most certainly appear as levels of maximum condensation; while the intervening regions, because less frequented by any one particular type, though possibly frequented by even a greater number of all types due to the overlapping, so to speak, of the characteristic types of adjacent vertical regions, would, nevertheless, according to such system of grouping be considered regions of minimum condensation. The crux of the problem really centers about the question of whether there is sufficient overlapping of the different types, peculiar to different altitudes, to compensate for the deficiencies on either side of the average level of each type, or what the effect of such overlapping of the different types.

THE CLOUD CHARTS.

Figure 1.—This figure represents the altitude at which each stratus or alto-stratus base was observed, at all seasons and all stations regardless of geographical location. The reason for adopting this particular scheme of grouping stratus with alto-stratus clouds should be obvious when we consider the striking similarity in the general appearance of these two cloud forms, and the common occurrence of different observers calling the same cloud different names. As a rule the stratus appears the denser of the two because it is nearer the observer and therefore intercepts more light, direct or scattered, from the sky. Moreover, it is quite probable that each type is formed essentially by the same processes. Evidently, then, the fundamental distinction between these two types is primarily one of altitude; and, since the estimation of altitude is always attended with considerable uncertainty, even by one skilled in cloud observations, it is not at all surprising to find unskilled observers recording stratus for clouds whose bases are afterward found to be 2,500 meters, and alto-stratus for clouds whose bases are below 1,000 meters. The International Meteorological Conference adopted the altitude of 1,000 meters as the line of demarcation separating these two types.

From an examination of this figure it will readily be seen that up to an altitude of 200 meters the frequency increases rapidly; gradually from 200 to 400 meters; then decreases quite rapidly to about 650 meters; somewhat gradually from 650 to 1,600 meters; then somewhat slowly and more or less irregularly up to the upper limits at which they have been observed. But while there appears to be no doubt as to the existence of a region of maximum frequency somewhere below 500 meters, with a rapid decrease above that level, the amount of available data is insufficient to justify any definite conclusions as to the rate of decrease above 1,600

[5] Cf. MO. WEATHER REV., Apr., 1919, 47: 210-225, and Dec., 1920, 48: 692-697.
[6] In manuscript lectures, Signal Corps School of Meteorology, July, 1918.

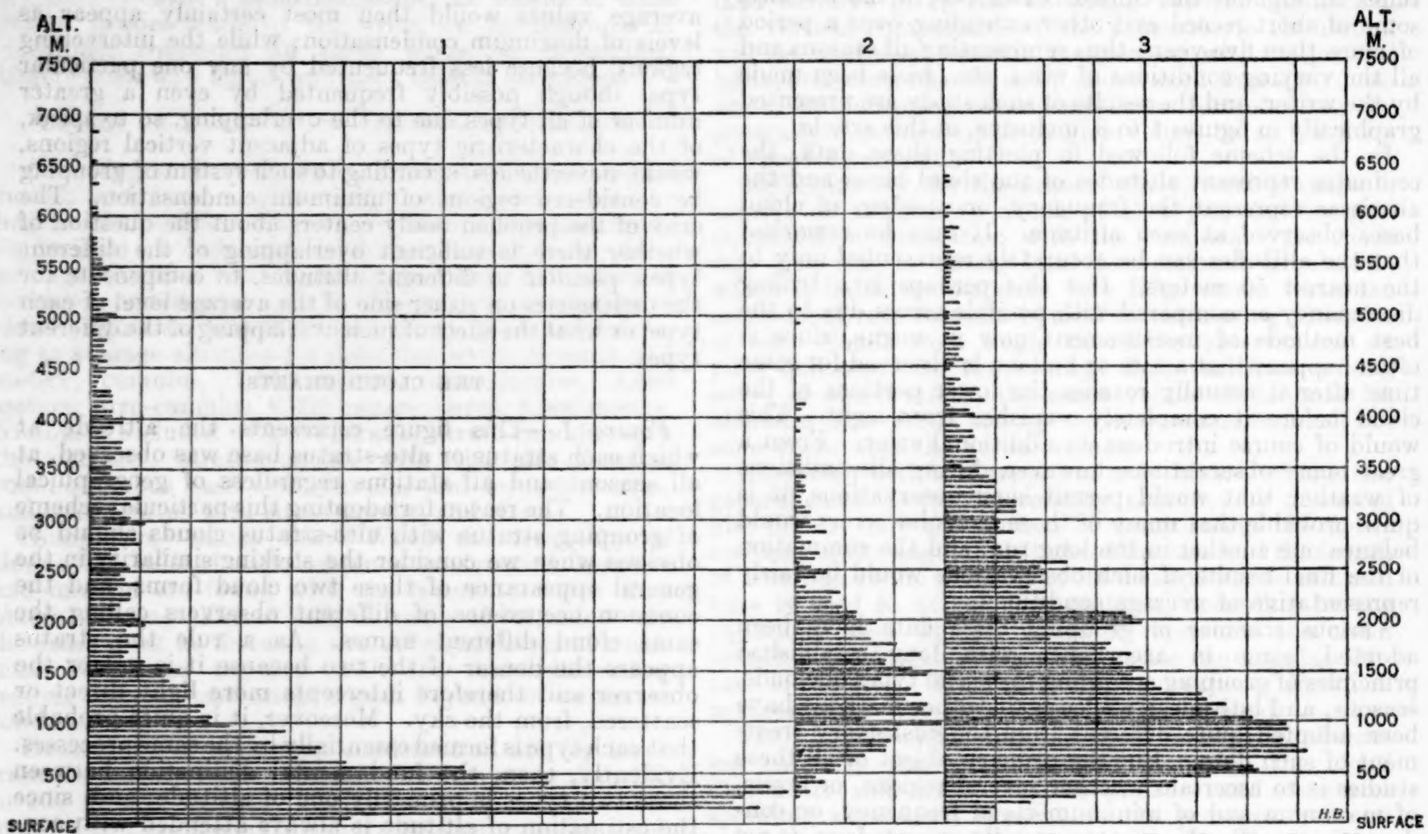
meters, or of the existence of alternate regions of secondary maximum or minimum condensation above this level. It is hoped that with future observations sufficient data of a more complete nature may be gathered to justify further conclusions in this regard.

The most salient feature brought out by figure 1 is that clouds of this type form at all altitudes from the surface to some high, upper limit, over 7 kilometers as shown here, and that any attempt to separate them according to altitude must therefore be impossible since such system of subclassifying them must necessarily be an arbitrary one.

Figure 2.—Since the cumulus and cumulo-nimbus types are quite distinct from all other cloud types, both in general form and appearance as well as in the causes and processes of their formation, they are therefore classified separately from their combination groups for charting. As before, in the case of the stratus and alto-stratus, all observations were grouped together in charting, regardless of season or of geographic location. As should most naturally be expected, the average "condensation level" at which these clouds are formed most frequently is found to be somewhat higher than that of the stratus type, ranging somewhere between 1,000 and 1,700 meters, with the slope of the frequency curve gradual above and below this level of maximum frequency. This feature agrees quite closely with the corresponding theoretical region that others have defined as a "level of maximum condensation."

Except in rare cases, where the cumulo-nimbus builds up massive, towering thunder heads, these clouds are found to exist principally below altitudes of 2,500 meters and almost entirely below 3,500 meters, the season being a chief determining factor, since relative humidity is dependent upon temperature for any given mass of air, and the temperature in turn is conditioned by seasonal changes. The methods of formation of both the cumulus and cumulo-nimbus are identical, due chiefly though not entirely to thermal convection.

Figure 3.—For the same reason that stratus and alto-stratus types were grouped together in figure 1, strato-cumulus and alto-cumulus types are grouped together in figure 3, including all observations during all seasons and in all geographic localities. The essential features that were brought out in figure 1 also appear in figure 3, viz, the rapid slope with increasing altitude to about 500 meters, followed by a gradual slope to a maximum somewhere between 750 and 1,050 meters, by a fairly moderate slope of 4,000 meters, and a gentle slope above. The salient feature of this chart, distinguishing it from figures 1 and 2, is that the region of maximum cloud frequency, or condensation, lies midway between those of the stratus and the cumulus types, as might logically be expected of the strato-cumulus type, as its name suggests. It thus appears that the theoretical region of minimum condensation between the stratus and the lower, or "foul weather," cumulus regions of maximum frequency is partly or quite wholly filled in by the blending or combination of these two types, and the hypothetical intervening region of minimum condensation between the stratus and cumulus levels has in reality no existence. Furthermore, the figure brings out quite clearly the fact that no intermediate gap due to minimum condensation exists between the so-called strato-cumulus and alto-cumulus



Frequency of cloud bases at different altitudes as determined from kite and balloon ascensions (all seasons, northern and southern stations):

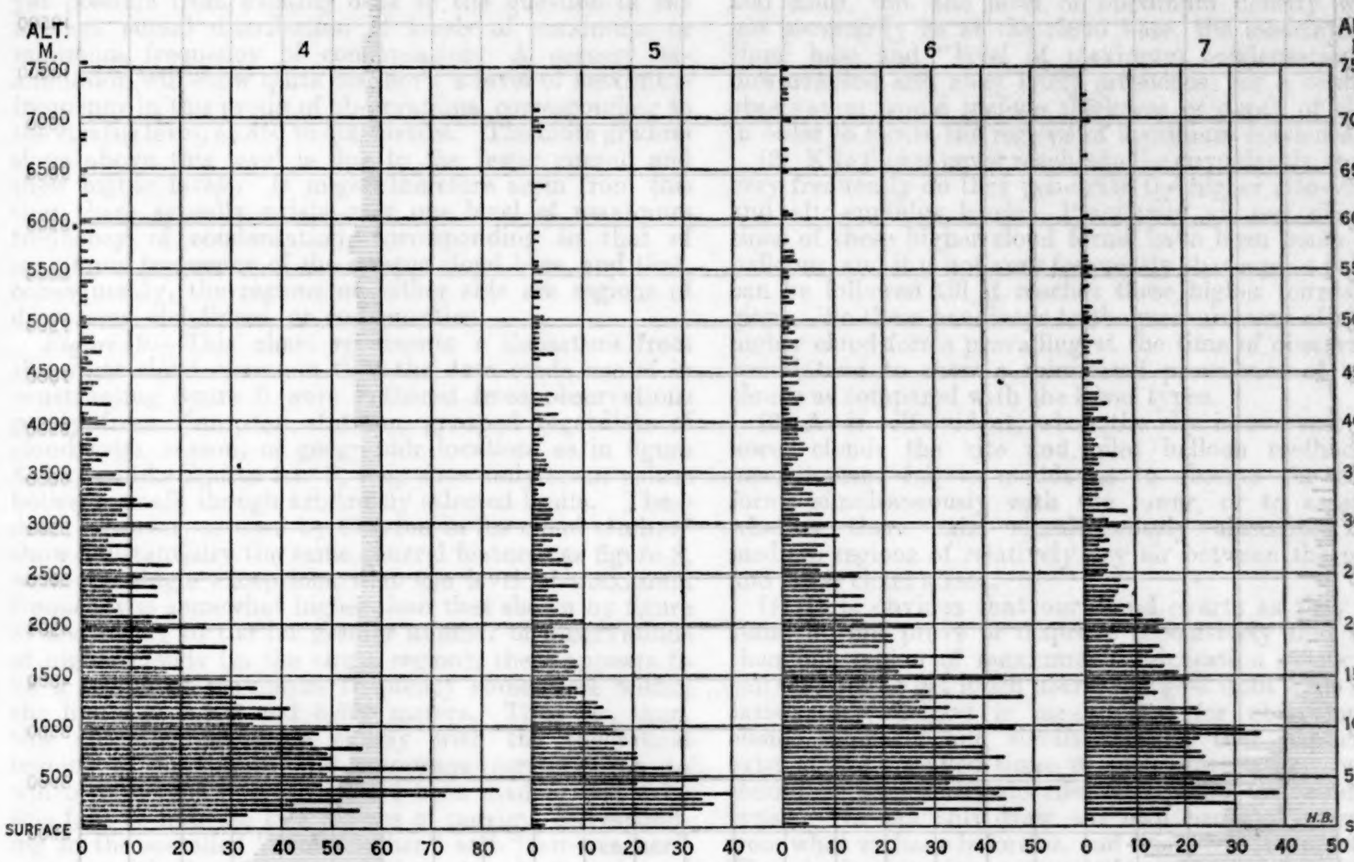
FIG. 1.—Stratus and alto-stratus. FIG. 2.—Cumulus and cumulo-nimbus. FIG. 3.—Strato-cumulus and alto-cumulus. (Ordinates represent altitudes in meters; abscissae, number of clouds observed.)

forms. This last feature would seem to indicate that the customary distinction between these two forms or types of cloud is based entirely on altitude, and therefore is arbitrarily made. It is a well-known optical principle, due to perspective, that the farther away any object is from the observation point the smaller it appears; hence, the alto-cumulus type, peculiar to fair weather and consequently higher altitudes, should appear smaller, as they do, and due to different relative distribution of light, they would appear more or less lighter and their blending of light and shadow more pronounced. These, indeed, are the chief distinguishing features between the alto-cumulus and the strato-cumulus types. It is not at all surprising, therefore, to find one observer calling a particular cloud A. Cu., and another calling the same cloud St. Cu., if we only bear in mind that different people estimate relative magnitudes as based upon apparent distance in a way to cause slight differences in the apparent diameter of the moon or other distant objects. In fact there is no sharp line of demarcation to distinguish the A. Cu. from the St. Cu. type, and the one gradually blends imperceptibly into the other type.

Figure 4.—Since the three preceding figures show different regions of maximum frequency corresponding to the different type forms, the question of there being regions of maximum frequency of condensation with alternate regions of minimum condensation when all the cloud types are considered simultaneously naturally enough presents itself for consideration. And if such theoretical regions do actually exist, at what average heights. Since it is also desirable to consider the varying influences of latitudinal and seasonal variation, it was decided to group all types with due regard to seasonal and latitudinal conditions. Accordingly, figure 6 represents such a grouping for all cloud forms observed during the winter half year at northern stations in the United States. This chart brings out the characteristic features of the foregoing charts, the level of maximum frequency being at an altitude of about 400 meters, corresponding to that of the most prevalent type of the season—the stratus. A notable difference, however, is to be observed in the more gradual slope of the chart in figure 4 above the level of maximum frequency. And again, this is exactly as might have been expected, since the strato-cumulus level of maximum frequency, a type common to the winter season, lies just above that of the stratus level.

Figure 5.—Precisely the same principle was followed in plotting this chart as in the preparation of figure 4, except that figure 5 consists of observations from stations in the southern latitudes of the United States, fewer in number and covering a somewhat shorter period of time. Although the number of observations from southern stations is comparatively small, the chart fails to show any increase in the average altitude of clouds with decrease in latitude, as is thought to be the case with the higher or cirrus types. While it is a generally accepted fact that, as observations have shown, the average height of clouds of the cirrus type increases with decrease in latitude, and also with the warm season, it does not necessarily follow that the same variation applies to the height of the lower clouds; furthermore, a comparison of figures 4 and 5 indicates quite conclusively that the same variation does not hold.

Figure 6.—Figure 6 follows the same scheme of grouping as figure 4, including all types for northern stations; but differs from figure 4 in that it includes



Frequency of cloud bases (all types) at different altitudes as determined from kite and balloon ascensions; winter (October to March, inclusive), summer (April to September, inclusive):

FIG. 4.—Northern stations. FIG. 5.—Southern stations. FIG. 6.—Northern stations. FIG. 7.—Southern stations. (Ordinates represent altitudes in meters; abscissae, number of clouds observed.)

only such observations as were made during the summer half-year. In contradistinction to the chart in figure 4, figure 6 shows a region of practically uniform frequency from 200 to 1,700 meters. This result is specially significant in that it indicates quite clearly that *the prevalence of the stratus, cumulus, and strato-cumulus types is about equal during the warmer season.*

is operative mainly during summer, over land surfaces at least. And lastly, the strato-cumulus type follows from the formation of the other types.

Figure 7.—In figure 7 the same principle was followed as in figure 6, plotting all cloud types observed during the summer season, but using only those data collected from southern stations. It is interesting to note that

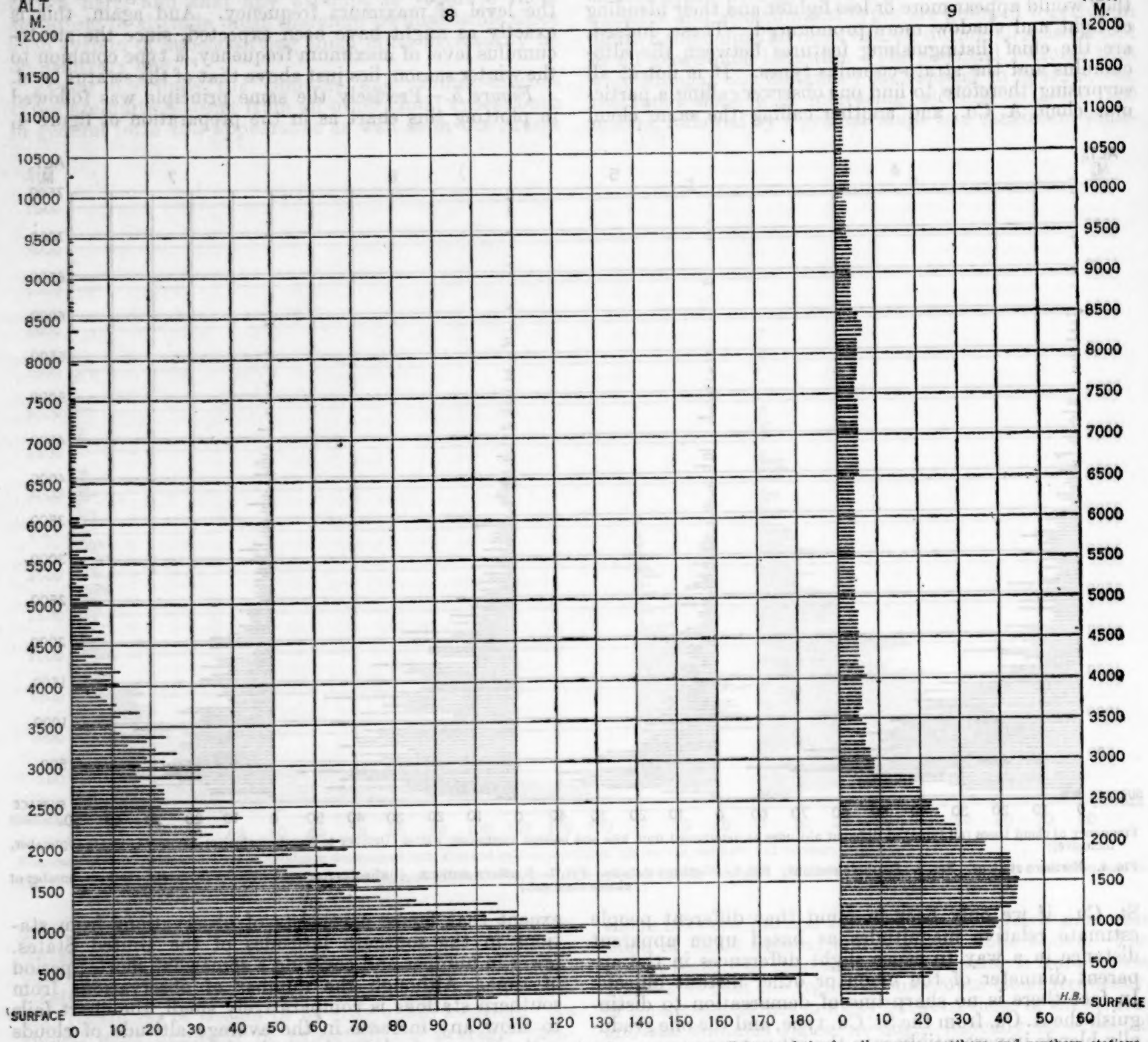


FIG. 8.—Frequency of cloud bases at different altitudes as determined from kite and balloon ascensions; all types of clouds, all seasons, northern and southern stations.
FIG. 9.—Frequency of clouds, as determined from double theodolite and other methods of observation, at Berlin, Upsala, Storlien and Blue Hill, for all types of clouds and all seasons. (Clayton, *loc. cit.*, p. 331.) (Ordinates represent altitudes in meters; abscissae, number of clouds observed.)

That this last condition is a perfectly reasonable inference is evident when we consider that the same processes that are supposed to be the chief processes of formation of the lower or stratus type are operative in summer as well as in winter, though perhaps to a somewhat less degree; while, on the other hand, the process peculiar to the formation of the purely cumulus type

the general features brought out by each chart are almost identical. Both show a deep stratum of practically uniform frequency between the limits of 200 and 1,700 meters, a comparatively rapid slope from 1,700 to 2,500 meters, and a gradual slope beyond 2,500 meters. As in figure 6, figure 7 also shows a comparatively equal frequency of the lower cloud forms. Another note-

worthy and interesting feature is the fact that a comparison of figures 6 and 7 as of 5 and 6, shows no increase in the average height of maximum frequency with decrease in latitude. Comparison of figures 4, 5, 6, and 7 shows that the level of maximum frequency of the lowest cloud type occurs at about 350 to 400 meters above the surface, regardless of season or latitude, and that the same disregard to season or to latitude applies equally to the higher St. Cu. and Cu. types

Figure 8.—On this is charted over 5,500 observations of all cloud types during all seasons, and at widely distributed stations representing all latitudes and longitudes throughout that portion of the United States east of the Rockies. This chart is the nearest answer yet possible from existing data to the question of the average actual distribution of levels of maximum or minimum frequency of condensation. A cursory examination will show quite distinctly a level of maximum frequency in this group of observations, corresponding to the stratus level, at 350 to 400 meters. The more gradual slope above this level is due to the fewer cumuli and their higher levels. It might therefore seem from this that there actually exists only one level of maximum frequency of condensation, corresponding to that of maximum frequency of the stratus cloud base, and that, consequently, the regions on either side are regions of decreasing cloudiness, or condensation.

Figure 9.—This chart represents a departure from the other cloud charts in that the data made use of in constructing figure 9 were gathered from observations partly from European stations, grouped regardless of cloud type, season, or geographic location, as in figure 8; but, unlike figures 1 to 8, they show only mean values between small, though arbitrarily selected limits. These data, however, as used by Clayton in his cloud studies,[7] show substantially the same general features as figure 8, with the single exceptions that the level of maximum frequency is somewhat higher than that shown by figure 8, and owing to the far greater number of observations of higher clouds (in the cirrus region), there appears to be a region of maximum frequency somewhere within the limits of 6,500 and 8,500 meters. Thus far, then, this chart agrees more closely with the theoretical regions of maximum and minimum condensation to which numerous references have been made. But even this fails to indicate two regions of maxima corresponding to the so-called "foul-weather" and "fair-weather" cumuli, with the consequent "intercumulus" region of minimum condensation.

CONCLUSION.

It must be admitted that the theoretical distribution of maximum and minimum condensation in the main seems logical and, in spite of *frequency* alone not showing them (frequency × amount of cloudiness), which has not been considered here, would probably prove its correctness.

From a cursory inspection of the foregoing cloud charts and a hasty consideration of the interpretation thereof, one might arrive at the conclusion that such charts furnish conclusive evidence that only one appreciable region of maximum frequency of condensation actually exists in the upper air, and that the region on either side is one of decreasing condensation. Indeed, this view seems quite tenable. But, in the light of the meager data available, and of our very inadequate methods of procuring thorough and reliable observations at all altitudes simultaneously and in all conditions of weather, such a conclusion may not be considered as final. There are many substantial reasons which compel us to suspend judgment for the present at least, and to await future development of new and more complete methods of cloud measurement:

(1) Our measurements of clouds refer mainly to their bases. Few measurements of cloud thickness or of cloud density have been made, owing to lack of convenient methods. Since, therefore, our present knowledge of these interesting conditions is extremely meager, and since, too, the level of maximum density would not necessarily be at the cloud base, the association of cloud base and "level of maximum condensation" is unwarranted and most likely erroneous; for a complete observation would include thickness or depth of clouds in order to locate the regions of maximum condensation.

(2) Kite flights never reach into the cirrus levels, and not very frequently do they penetrate the higher alto-stratus and alto-cumulus levels. Practically all our observations of these higher cloud forms have been made with balloons, and it is not very frequently that a pilot balloon can be followed till it reaches these higher (cirrus) regions. So these handicaps to the measurement of all the higher cloud forms prevailing at the time of observation would tend to show a minimized prevalence of upper clouds as compared with the lower types.

(3) As is self-evident, when the sky is overcast with lower clouds the kite and pilot balloon methods of measurement fail to enable us to observe the higher forms simultaneously with the lower, or to ascertain whether there exist simultaneously alternate intermediate regions of relatively dry air between the upper and lower cloud strata.

(4) It is obvious that our cloud charts as they now stand do not prove or disprove conclusively that more than one region of maximum condensation exists; nor can we hope to get much nearer our goal until some more satisfactory method is inaugurated for observing all clouds regularly and simultaneously, that happen to exist at the specified times of such observations, which should be sufficiently distributed equally to include all types. We can only draw our own personal inferences from what we have before us, and this is left to the reader. They do, however, seem to justify the conclusion that at least one, and possibly two, regions of maximum *frequency* of condensation exist.

Moreover, the observations seem to establish the fact quite conclusively that neither latitude nor season produces any appreciable change in the average altitude of the lower clouds, as is supposed to be the case with the higher clouds.

THE VERTICAL EXTENT OF CLOUD LAYERS.[1]

By W. PEPPLER.

[Abstracted from *Meteorologische Zeitschrift*, January, 1921, pp. 18-21.]

This paper is a continuation of the discussion of measurements upon clouds at Lindenberg, covering a period of 11 years of observations with kites and captive bal-

[7] *Ibid.*, p. 334.

[1] *Die vertikale Erstreckung der Wolkenschichten und die Wolkentagen über Lindenberg.*

loons. This note is concerned chiefly with the mean thickness of cloud layers. The results for the different cloud types are as follows:

Stratus.—Thickness less than 400 meters in greatest number of cases; very seldom greater than 600 meters; mean thickness, 320 meters. There appears to be little seasonal difference.

Nimbus.—The difficulties of observation are very much greater, but the mean thickness of 800 meters is obtained. This is based on a smaller number of observations, due to the fact that under conditions when nimbus prevail, ascents are difficult.

Cumulus.—89 observations gave a mean thickness of 500 meters.

Strato-cumulus.—This layer presented easier determinations because of the attendant discontinuities in temperature and humidity; layers less than 500 meters in thickness were predominant; mean thickness, 310 meters.

Alto-cumulus and alto-stratus.—It is seldon that this level was attained by the registering instruments, and often the clouds were of such a flaky character as to render determinations of thickness difficult; mean thickness for A. Cu., 120 meters, for A. St., 300 meters.

On the whole these values are not in bad agreement with those of Süring at Potsdam. From these means, and from the mean heights of the lower surface of the various cloud types, it is possible to construct a schematic vertical section of the atmosphere above Lindenberg. This the author does, and it appears that there are three layers in which the clouds do not frequently occur—designated by Wenger and Köppen as *wolkenfrei Räume.* These are (1) from the surface to 500 meters; (2) between 1,300 and 1,400 meters—this level being somewhat in doubt; and (3) between 1,900 and 3,000 meters. Too much weight is not given this diagram by the author, and he remarks that "it has only the value of a schematic representation of a cloudy day, but, owing to the numerous observations, it probably approaches closely to the truth."—*C. L. M.*

ANALYSIS OF CLOUD DISTRIBUTION AT ABERDEEN, SCOTLAND,[1] 1916-1918.

By G. A. CLARKE.

[Reprinted from *Science Abstracts*, Sec. A, Jan. 31, 1921, §26.]

The cloud distribution is analysed from the point of view of aerial navigation. Cloud observations are taken at Aberdeen at 7h., 9 h., 13 h., 15 h., 18 h., 21 h., and to each day is assigned in addition a "cloud characteristic" indicating the kind of cloud which predominated, the lowest type taking precedence over higher ones if covering four-tenths of the sky or more. The day is "clear" if on the average the total amount of sky covered is less than four-tenths, while certain days of very mixed or rapidly changing cloud are classed as "various." Taking cumulus and cumulo-nimbus together, they are found to give the most frequent skies, 23 per cent of the total, while other low clouds are numerous. Alto-stratus skies are twice as frequent as alto-cumulus, but cirro-stratus and cirro-cumulus skies are of equal frequency. Using the average heights of the various types together with the cloud characteristic, 15 per cent of days are seen to be cloud-free below 15,000 feet, 26 per cent below 7,000 feet, 69 per cent below 3,000 feet, while the remaining 31 per cent of days have cloud predominating below 3,000 feet. Seasonal distribution is discussed. The frequency of cumulus and cumulo-nimbus taken together is found to be greatest in April, and there are secondary maxima in mid-summer and September. Air conditions should be most bumpy at these periods. Strato-cumulus skies are more common in winter than in summer, and there are indications that skies well covered with intermediate and higher clouds are also more frequent in winter, but the observations depend on the presence or absence of lower cloud.—*M. A. G.*

[1] Meteorological Office, London, *Professional Notes No. 9*, 1920, pp. 142-147. Cf. also, Brunt, D.: On the inter-relation of wind direction and cloud amount at Richmond (Kew Observatory), *ibid.*, No. 1, 1918, 11 pp.; Diagrams illustrating the amount of cloud during summer and winter with winds from different directions, at Kola and Archangel, *ibid.*, No. 7; The Climate of Northwest Russia, 1919, p. 94; Brunt, D.: Tables of frequencies of surface wind directions and cloud amounts at Metz, Mulhausen, Karlsruhe and Frankfurt, *ibid.*, No. 14, 1920.

THE ARGONNE BATTLE CLOUD.

By B. M. VARNEY.

[University of California, June 22, 1921.]

Descriptions of unusual clouds that were formed in the wakes of airplanes flying over the Argonne battle front in the autumn of 1918 has since been published by eyewitnesses. Mr. G. B. Vaughn wrote[1] as follows:

> We were passing through a little town * * * when we noticed three parallel lines of clouds or smoke stretching far across the sky. They looked as if they had been made by three planes passing, throwing out smoke and cutting stunts, for the lines were far from straight. Through these lines were waves which ran perpendicular to the earth, with a drift from left to right. They looked most like waves of heat one sees rising from the earth, but they traveled with a shifting motion somewhat like the flickering of the northern lights.

Capt. W. F. Wells, Sixtieth Infantry, American Expeditionary Forces, wrote:[2]

> There were two or three days of rain, when came a wonderfully clear and beautiful morning, with not a cloud in sight. * * * Our attention was first drawn to the sky by the sudden appearance of several strange and startling clouds—long, graceful, looping ribbons of white. These were tapering to a point at one end, and at the other, where they dissolved into nothingness, sixty degrees across the sky, were about as broad as the width of a finger held arm's distance from the eye. On close observation we noticed some distance ahead of each cloud point the tiny speck of a chase plane. Apparently the churning of the air was all that was needed to upset the delicately balanced meteorological conditions and precipitate this strange cloud formation. * * * Never before had I seen a plane writing in white upon the blue slate of the sky.

Capt. W. H. Nead, One hundred and sixty-eighth Infantry, described the phenomenon[3] thus:

> The Rainbow Division, on the morning of October 10, 1918, was lying in what had at one time been a wood just back of Montfaucon. The sky was clear except for a few fleecy clouds to the northwest. Three airmen came from the northwest and passed almost over our regiment, continuing on to the southeast.
>
> Behind each machine was a trail of white, which at first sight appeared to be smoke resulting from poor engine combustion, but which upon more careful observation proved too wide to have been caused by smoke. Perhaps the strangest thing of all was the fact that when the planes reached a certain point in the sky the rainbow (sundog) colors became distinctly visible.
>
> The explanation is not difficult. The air was almost saturated with moisture at the temperature which prevailed at that altitude. With the passing of the planes, the propeller movements caused a strong air current with a lowering of the temperature where the current was noticeable. With the lowering of the temperature the air became supersaturated with moisture, forming a small cloud, which at that altitude immediately became snow. This snow would give the white appearance * * * and would also account for the rainbow colors.

The attainment of the saturation point being necessary to condensation, the methods by which this may be

[1] *Am. Legion Weekly*, Sept. 24, 1920, p. 28.
[2] *Scientific American*, June 7, 1919.
[3] *Am. Legion Weekly*, Oct. 22, 1920, p. 12.

brought about in this particular case are of interest. It could scarcely be the result of a reduction in temperature due to the stirring, *per se*, of the air by the propeller. An increase in the moisture content of the air is probably involved. Of the two following suggestions as to the origin of the cloud the first, and probably the correct one, was made by Prof. Humphreys:

The end products of complete combustion of gasoline are water vapor and carbon dioxide, and it is found that if the water vapor were condensed, there would result a little more than 1 gallon of water per gallon of gasoline consumed. It was found by Wells and Thuras, in studying the fogs off the Newfoundland coast (see *U. S. Coast Guard, Bull. 5*, 1916) that there were 1,200 water droplets of diameter 0.01 mm. in a cubic centimeter of air in a dense fog. If we assume that an airplane travels 3 miles on a gallon of gasoline (approximately the figure given by the Aerial Mail Service) it is possible to show that if only a small part—a fourth or fifth—of the water vapor were condensed, there would be abundant cloud to produce the effect observed at the Argonne Battle. It should be stated, however, that this water vapor would have to be discharged into air which was very cold and nearly saturated. This seems to be the correct explanation, and is substantiated by scientists at the Bureau of Standards, who say that they have actually observed this cloud behind airplanes and automobiles. The Bureau of Standards is working on a device for condensing and using this water aboard dirigibles as ballast.

The second suggestion, by the writer of this note, is in harmony with experimental results, though whether the necessary conditions can exist in the free air is a question. It is suggested that it may be possible for supersaturation to occur in the atmosphere and for shock of some sort to induce condensation in air in which this unstable condition exists. Color is perhaps lent to this speculation by the facts that condensation has been induced, experimentally, in supersaturated air, by shock, and that the supercooling of water droplets is a recognized process in the free air. Mr. K. C. M. Douglas has shown [4] "that clouds consisting of supercooled water droplets may exist more than 10,000 feet above clouds consisting of ice crystals," and at temperatures at least 43° F. below the freezing point of water, and that shock of impact with his plane caused the instant freezing of the droplets. In the case of the Argonne Battle cloud, the question is therefore raised as to whether supersaturation can occur in the free air, and whether atmospheric vibrations set up by the exhausts from the engines would be a sufficient cause of condensation in such air. If such were the case, the volume of air involved would doubtless be great enough to furnish water vapor sufficient to form a visible cloud.

FROST SUPERSATURATION (FROSTÜBERSÄTTIGUNG) AND CIRRUS.

By ALFRED WEGENER.

[Abstracted from *Meteorologische Zeitschrift*, Jan.-Feb., 1920, pp. 8-12.]

It is possible to find conditions of vapor pressure and temperature, in which the space over ice is saturated, but over under-cooled water at the same temperature it is not saturated. The author has given this condition the name *Frostübersättigung*, or frost supersaturation. There exists a point, known as a triple point, at which water, ice, and undercooled water may exist side by side. The coordinates of this point are e (vapor pressure) $= 4.57$ mm., and t (temperature) $= +0.0075°$ C. At temperatures below this point evaporation will cease to take place from an ice surface at a slightly lower vapor pressure than from an (undercooled) water surface at the same temperature. In other words, over a small range of vapor pressure condensation may be occurring on ice at the same time that water at the same temperature is evaporating. The point of maximum difference of vapor pressure, amounting to 0.2 mm., occurs at a temperature of $-11.4°$ C.

Some of the consequences of this physical relation are pointed out. It has often been observed in free-balloon ascents that, above the 0° C. isotherm, undercooled water droplets and snow crystals may simultaneously occur. But the water droplets are evaporating and the snow crystals are growing larger, with the result that water eventually disappears. This is the spectacle afforded by the streaks of falling snow above which the mother cloud has entirely evaporated.

Many observations have been made in Greenland of cases in which the air has been supersaturated with respect to ice but not to water. The result has been that large crystals of ice have been seen to form on the snow. In addition, occasionally with a higher relative humidity, fog has formed after the ice crystals have appeared. In the case where this crystal-forming stage has been followed by a rise in temperature and a consequent fall in humidity, the ice crystals have disappeared. This phenomenon can occur in clear weather.[1]

The author gives other examples: On a day with a temperature of $-40°$ C., a cloud 3 km. in length was seen in Greenland, stretching away from a chimney. During three airplane flights over Munich at a height of 9 km. a cloud 50 km. in length was formed. That it was composed of ice crystals was proved by the fact that the 22° halo was observed. This cloud the author attributes to the nuclei furnished by the motor exhaust.[2] A horse, warm from running over the ice, on a cold day in Greenland, was accompanied by a cloud 50 meters in height formed from its breath. Von Hann gives a similar case regarding a herd of reindeer. The human breath also has been seen to transform itself into small clouds of ice needles. These are also attributed to nuclei discharged into the air.[3]

The condition of frost supersaturation may be responsible for the apparent self-sustaining nature of cirrus wisps. It may be that the cirrus particles, forming at high elevations fall into supersaturated layers. The crystals of the cirrus act as nuclei for growth, and the consequence is that the layer changes from a state of supersaturation to one of saturation and the cloud appears to spread out and become heavier merely by virtue of the ice formed upon the falling crystal.—*C. L. M.*

ON THE FREQUENCY OF FOGS IN THE EASTERN SAHARA.

By J. TILHO.

[Abstracted from *Comptes Rendus*, Paris Acad., June 14, 1920, pp. 1435-1438.]

It has often been observed that during December and January the west coast of Africa, particularly that in the vicinity of the Gulf of Guinea, is visited by northeast winds accompanied by persistent fogs, which seemed to be constituted quite largely by fine dust particles sup-

[4] Douglas, C. K. M.: Optical phenomena and the composition of clouds. *Jour. Scot. Metl. Soc.*, Vol. XVIII, 3d series No. XXXVI, pp. 83-86.

[1] Such frost can also form when the ice-surface temperature is below the (ice) dew-point of the air—without frost supersaturation in the space above the ice.—EDITOR.

[2] Capt. Walter H. Nead in the *American Legion Weekly* of Oct. 22, 1920, relates the formation of long cirrus clouds in the wake of three airplanes in the vicinity of Montfaucon, France, on Oct. 10, 1918. At first the trails were thought to be smoke, but they proved to be too wide for smoke. Their ice-crystal structure became evident when halo phenomena were observed as a result of their presence. Cf. "The Argonne Battle Cloud." This REVIEW, pp 348-349.—EDITOR.

[3] The moisture without the nuclei discharged would be ample to make such clouds, therefore, the nuclei merely assure the formation of the cloud which would probably form anyway.—EDITOR.

posed to have come from the desert or semidesert regions. Similar fogs have also been observed along the Niger River, in Zinder, and around Lake Chad. While in the Borku Oasis (northeast of Lake Chad) the fogs observed were remarkable for their extreme dryness, as is attested by the following table:

Date of fog and hour of observation.	Temperature.		Relative Humidity.	Wind.	
	Dry-bulb.	Wet-bulb.		Direction.	Speed.
	°C.	°C.	Per cent.		Meters per second.
Dec. 4, 1914:					
6 a. m.	18.9	9.1	17	NE.	12
12 m.	25.8	12.4	12	NE.	15
3 p. m.	21.5	11.8	24	NE.	12
Dec. 5, 1914:					
6 a. m.	15.3	6.9	19	NE.	18
12 m.	21.0	9.8	13	NE.	22
9 p. m.	18.0	8.9	20	NE.	16

State of the atmosphere: Heavy fog with visibility limited to about 300 to 400 meters.

Owing to the frequence and duration of these dry fogs of the Sahara, they are of importance to aviation. Observations were carefully made from May, 1914, to April, 1917, at Borku, three times a day. The following scale was used in estimating the intensity of fogs:

Heavy fog.................................Visibility limited to 0.5 km.
Moderate fog............................Visibility limited to 3 km.
Light fog..................................Visibility greater than 3 km.

Distances were estimated in the daytime by certain known groups of palm trees, rocks, etc., while at night they were indirectly estimated by observing the various magnitudes of visible stars. The number of fogs so observed were as follows:

Year and month.	Number of fogs observed.			Total number of observations.	Per cent.
	Heavy.	Moderate.	Light.		
1915, 1916, 1917:					
January	10	32	42	273	15.4
February	29	20	40	257	19.0
March	13	21	34	279	12.2
April	24	21	45	245	18.4
1915, 1916:					
May	5	13	18	181	10.0
1914, 1915, 1916:					
June	22	26	48	269	18.0
July	21	17	38	275	13.8
August	13	12	25	177	9.0
September	1	10	11	261	4.2
October	4	2	6	263	2.3
November	0	8	8	265	3.0
December	16	37	53	276	19.2

It appears from the table that the time of greatest fog frequency is that between the winter and summer solstices, while the northeast winds dominate the region. From August to November, when the west and southwest winds are dominant, there are fewer fogs. The northeast fog-producing winds are persistent and blow with great violence for many days at a time, and generally reach maximum about 10 a. m. and a minimum about sundown.

While it is difficult to estimate the depth of these fogs, it is certain that they are often deeper than the highest rocks at Borku, which extend upward 250 to 300 meters.

As the speed of the wind increases it is observed that the intensity of the fog increases. With winds above 8 or 10 meters per second the fog recorded is usually heavy; below that speed, it is light. As the wind dies down, the dust particles settle out of the air to the ground, and the visibility becomes equal to that in France on the best days, and it is often possible to see from 100 to 120 kilometers.

Sand storms.—These storms are frequently observed with such violence as to quickly bury small objects, such as boxes, camp equipment, etc. Pebbles the size of a hazelnut and minute crystal of quartz serve to make exposure to such a storm very uncomfortable. Static electrical phenomena are frequently observed under such conditions.—*C. L. M.*

ON THE DIFFERENCES BETWEEN SUMMER DAYTIME AND NIGHTTIME PRECIPITATION IN THE UNITED STATES.

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., July 10, 1921.]

Several studies have been made of the hourly distribution of the amount of precipitation in many parts of the world, and the results of most of these have been given in Hann's *Lehrbuch der Meteorologie* (3d edition, pp. 338–346). A later paper [1] shows both in tables and by chart (reproduced here as fig. 1) the various percentages of the 24-hour rainfall in different portions of the United States that occur at night during the summer. The inequalities between the day and night precipitations here shown are both interesting and important, and hence need to be explained.

In most, if not all, parts of this country, as also nearly everywhere else, the day and night distribution of summer rainfall is substantially the same as, and owing to, the corresponding distribution of the thunderstorm. And, since this type of storm is caused by a strong vertical convection of air containing a considerable amount of water vapor, it follows that summer precipitation is divided between day and night in substantially the same proportion as is the strong vertical convection of tolerably humid air.

In the southeastern portion of the United States where the prevailing summer winds are southerly (hence humid) and gentle most of the rainfall of this season is due to heat thunderstorms—that is, local thunderstorms resulting from convection induced by strong surface heating. Hence in this section summer rains are most frequent about mid afternoon.

Similarly, throughout much of the Rocky Mountain and Plateau regions, especially about the chimney-acting peaks and other places favorable to strong updrafts, cumuli and the resulting precipitation are most frequent during summer, in the afternoon, and least frequent at night.

Through the northeastern portion of the United States the typical heat thunderstorm is of secondary importance. Nevertheless, its occurrence there appears still to be often enough to account for the slight excess in that region of the daytime over the nighttime precipitation.

There remain for consideration the regions in which the summer rain is most abundant by night.

One of these regions is the lower Michigan peninsula. Here, as elsewhere, rain at any given place and time is due to clouds that had their inception to the windward. In general, therefore, the rains over the lower Michigan peninsula are from clouds that either originated above or crossed over Lake Michigan. Now, during summer the land areas about this lake, as, in general, about all lakes, commonly are warmer through the day than the surface of the water and cooler at night. Hence, convection over the lake and, consequently, the cloudiness and precipitation to the near leeward—that is, over the lower peninsula—are greatest at night.

[1] Kincer, J. B., MONTHLY WEATHER REV., Nov., 1916, 44; 628-632.

The extreme southwestern portion of the United States appears also to get most of its summer precipitation at night. Here the air that rises during the day, being over hot desert regions, is too dry, except rarely, to yield any considerable precipitation. Furthermore, any daytime rain that may fall as the result of a local convection must be from a high cumulus and through more or less dry air. Hence the daytime catch in this region is reduced, often greatly reduced, by the evaporation in mid-air.

The nighttime catch presumably is greater than that of the daytime, as indicated by the rather scanty data, because (*a*) when the wind at the cumulus level is from the general direction of the Gulf of California the night rain obviously must predominate, owing to the fact that the ascending night air, being over the Gulf, is humid in comparison with the daytime convective columns that rise from the desert; and (*b*) the percentage of the rain lost by evaporation while falling is less at night than through the day, owing to the lower level of the night clouds, and the greater relative humidity of the air at that time.

Finally, summer precipitation is greater at night than during the day over a large area that is centered, roughly, in eastern Nebraska.

Cold anticyclones, cold because of considerable southward travel over land, frequently enter the United States by way of Montana, or anywhere east to and including the Great Lakes. It is these cool anticyclones that "break" the "hot waves" of the Mississippi, Missouri, and Ohio Valleys. On such occasions thunderstorms are frequent in the region under consideration (*a*) when, in conjunction with an anticyclone over Montana, say, the pressure is high also over the eastern and southeastern portions of the United States, and, consequently, a north-south or northeast-southwest "trough" of low pressure lies over eastern Nebraska and adjacent regions; (*b*) when there is a LOW, or cyclone, in the Southwest, over New Mexico, for instance, and a cold anticyclone centered just north of the Great Lakes.

Under each of these, and similar, conditions, eastern Nebraska and the adjacent regions are likely, during summer, to be quite warm, and the surface pressure more or less below normal. At a kilometer elevation, however, and for some distance above that level, the pressure over the heated region may, during the daytime, be approximately equal (owing to expansion of the air below) to that over the anticyclone, and hence the winds at that level correspondingly gentle.

At night the warmer region normally loses heat more rapidly than the cooler, and hence the pressure at any considerable elevation above the former tends to fall below that of the latter at the same level. This in turn allows the cooler air here and there to overflow the warmer and thereby establish that convectional instability essential to the genesis of the thunderstorm.

Hence, in part at least, in the central portion of the United States the thunderstorm is more frequent and the summer precipitation more abundant during the night than in the daytime.

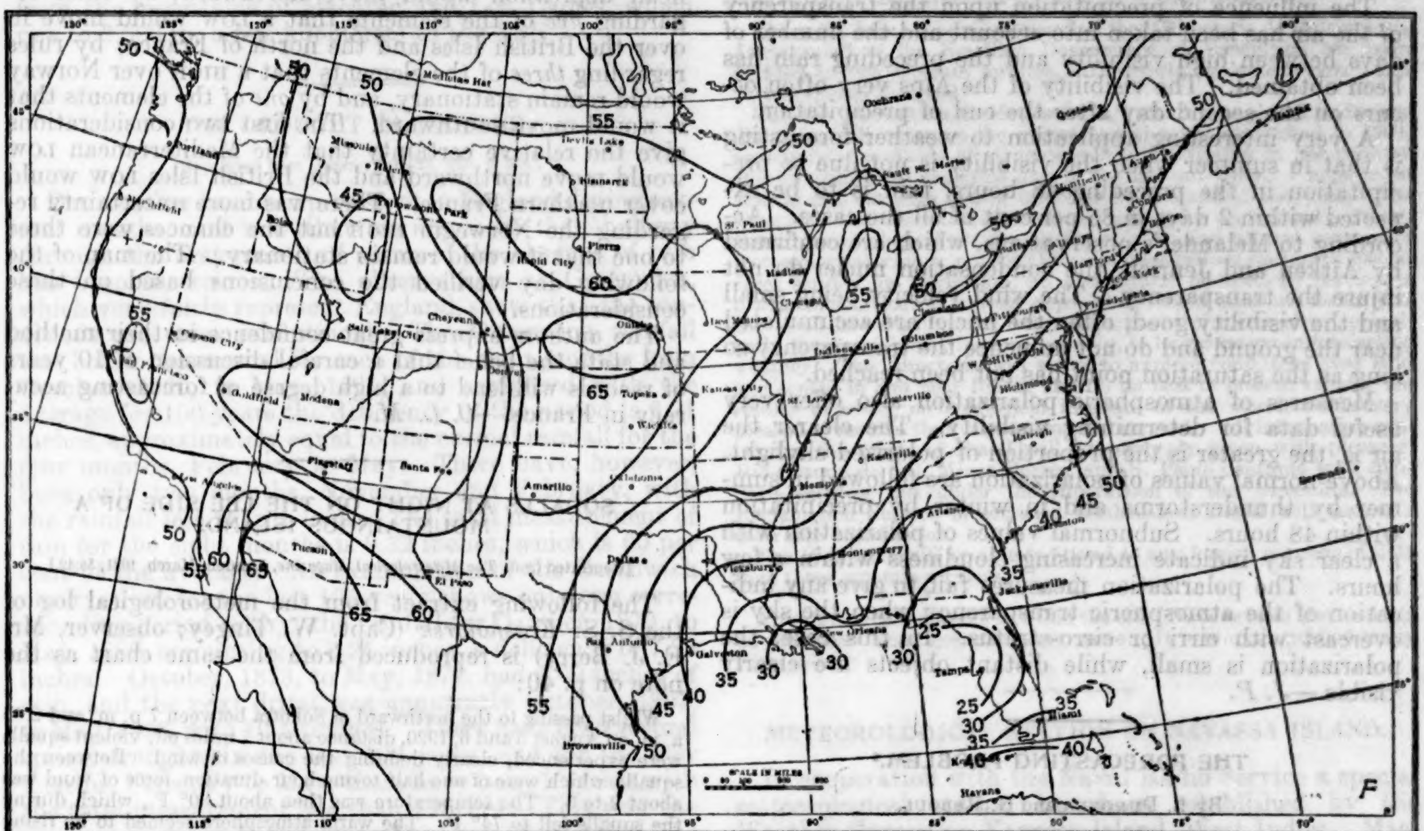


FIG. 1.—Percentage of average precipitation for the season, April to September, inclusive, 1895–1914, that occurs at night (8 p. m. to 8 a. m.). Based on about 175 Weather Bureau stations. Seventy-fifth meridian time.

NOTES, ABSTRACTS, AND REVIEWS.

VISIBILITY AND WEATHER FORECASTING.[1]

By A. GOCKEL.

[Abstracted from *Meteorologische Zeitschrift*, March, 1921, pp. 78-82.]

A high degree of visibility of distant terrestrial objects generally indicates that rain is soon to be expected. From 15 years' observations of the visibility of the Bernese Alps made from Freiburg (Switzerland), the conclusion is that rain follows within two days after high visibility, in 72 per cent of the observed cases.

The influence of precipitation upon the transparency of the air has been taken into account and the number of days between high visibility and the preceding rain has been obtained. The visibility of the Alps very often occurs on the second day after the end of precipitation.

A very interesting application to weather forecasting is that in summer when the visibility is not due to precipitation in the preceding 48 hours, rain is to be expected within 2 days in 85 per cent of all the cases. According to Melander's observations, which are confirmed by Aitken and Jenrich, the condensation nuclei do not injure the transparency. The wind velocity being small and the visibility good, often the nuclei are accumulated near the ground and do not influence the transparency so long as the saturation point has not been reached.

Measures of atmospheric polarization also offer very useful data for determining visibility. The clearer the air is, the greater is the proportion of polarized skylight. Above-normal values of polarization are followed in summer by thunderstorms and in winter by precipitation within 48 hours. Subnormal values of polarization with a clear sky indicate increasing cloudiness within a few hours. The polarization measures fail to give any indication of the atmospheric transparency when the sky is overcast with cirri or cirro-stratus. In this case, the polarization is small, while distant objects are clearly visible.—*J. P.*

THE FORECASTING PROBLEM.[2]

By L. DUNOYER and G. REBOUL.

[Abstracted from *Le Journal de Physique*, May, 1921, pp. 129-139.]

Called upon for information by the Bombardament Groups of the French Air Service, the authors established a meteorological station near Nancy in 1915, and proceeded to give daily meteorological reports and forecasts for the following 24 hours. At first an attempt was made to employ exclusively the rules of forecasting devised by G. Guilbert, but experience necessitated a departure from this method.

The following reports and data were available: (1) Synoptic reports furnished by the Bureau Central Météorologique, which covered western Europe, and enabled the isobaric map to be drawn; (2) aerological soundings, made at the home station and others along the front; (3) local observations of barometer, thermometer, hygrometer, and anemometer, and the *state of the sky*. A numerical measure of the accuracy of the forecast (*coefficient de certitude*) was employed and was arrived at in a mechanical way.

Many rules were employed, each having to do with a specific phenomenon, as, for example, deductions regarding the barometric distribution from barometric tendency; wind tendency (decreasing or increasing wind velocity), wind directions,[3] both at the surface and aloft; temperature tendency; the direction of movement and speed of cirrus clouds.[4]

An example of the meteorological situation in France on January 24, 1917, is given in tabular form, and shows the method of arriving at the odds in favor of the forecast. For instance, it was indicated independently by rules regarding *six* of the weather elements that a Mediterranean depression would move northward; by rules regarding *five* of the elements that a LOW would move in over the British Isles and the north of France; by rules regarding *three* of the elements that a HIGH over Norway would remain stationary, and by *one* of the elements that it would move southward. The first two considerations give the relative certainty that the Mediterranean LOW would move northward and the British Isles LOW would cover northern France. There was more uncertainty regarding the Norwegin HIGH but the chances were three to one that it would remain stationary. The map of the following day verified the conclusions based on these considerations.

The authors express great confidence in their method and state the belief that a careful discussion of 10 years of records will lead to a high degree of forecasting accuracy in France.—*C. L. M.*

SQUALLS AT NIGHT ON THE LEE SIDE OF A MOUNTAINOUS ISLAND.

[Reprinted from *The Meteorological Magazine*, London, March, 1921, 56:42.]

The following extract from the meteorological log of the S. S. *Krasnoiarsk* (Capt. W. Tingey; observer, Mr. E. J. Berry) is reproduced from the same chart as the note on p. 40:

> Whilst passing to the northward of Sokotra between 7 p. m. and 2.30 a. m. on August 5 and 6, 1920, distance about 7 miles off, violent squalls were experienced, clearly defining the causes of wind. Between the squalls, which were of one-half to one hour duration, force of wind was about 2 to 3. The temperature was then about 80° F., which during the squalls fell to 74° F. The warm atmosphere seemed to be rising and forming cloud in the zenith, the cooler air rushing in to take its place, sweeping obliquely from the mountains, causing squalls of about force 8. Before and after clearing the lee of the island the force of monsoon was 5.

Sokotra is an island in the Indian Ocean, about 200 miles from the Arabian coast. Its length from east to west is 71 miles, its greatest breadth 22. The peaks of the central mass rise to about 4,000 feet. The log of the *Krasnoiarsk* shows that the sea temperature was about 70° F.

THE CHARACTERISTICS OF GALES ON THE COAST OF VENEZUELA.

[Reprinted from *The Meteorological Magazine*, London, March, 1921, 56:42.]

A note received from Senor L. Ugueto, Director of the Observatorio Cajigal, states that the season of gales on the coast of Venezuela extends normally from December to the middle of March, but occasionally begins even in October. The wind blows from W. or NW. on several

[1] *Durchsichtigkeit der Atmosphäre und Wetterprognose.*
[2] *Le problème de la prévision du temps.*

[3] *Cf.* Reboul and Dunoyer: Wind circulation as a basis for forecasting the location of pressure areas. Abst. in Mo. WEATHER REV., April, 1920, 48: 221.
[4] *Cf.* Reboul and Dunoyer: On the use of cirrus in the forecasting of weather. Abst. and disc. in Mo. WEATHER REV., March, 1920, 48: 156.

successive days, reaching a maximum in the afternoon or early evening, and falling off in the night and early morning. The winds are cold, bringing temperatures of 45° F. or even less, and humid, but they are accompanied by a clear sky with only a few sirrus or cirro-cumulus clouds. They are generally associated with a slight fall of the barometer. At other seasons of the year less violent winds from the same direction bring overcast skies and heavy rain.

The gales from E. or SE. are less violent; they occur always between noon and 16 h. [4 p. m.], are warm and dry, with a clear sky, and have no appreciable relation to the barometer. They are evidently Föhn-like winds from the mountains of Macarao and Los Teques, which rise to 2,500 m. a few kilometers to the ESE.

THE DROUGHT IN ENGLAND.

[Reprinted from *Nature*, June 23, 1921, p. 535.]

Dry weather has been persistent in England during several months, and now that we are more than halfway through the first month of summer the absence of rain has become serious. The observations at Greenwich, which very fairly represent England, show that the conditions are most exceptional. The Greenwich rainfall was below the normal for each of the eight months from October, 1920, to May, 1921, and compared with the average for 100 years the deficiency of the period is 6.21 inches, approximately equal to the normal rainfall for the four months, February to May. There have, however, been only two months, November and February, with the rainfall less than 1 inch. The total measurement of rain for the eight months is 9.32 inches, which is 60 per cent of the average. An examination of the Greenwich observations for the last 105 years shows only one corresponding period as dry, the rainfall for October, 1879, to May, 1880, amounting to 8.24 inches, a deficiency of 7.29 inches. October, 1873, to May, 1874, had 9.60 inches of rain, and the next driest was apparently October, 1897, to May, 1898, with 10.50 inches. There have been several spring droughts in the last 100 years, and for the four months, February to May, there have been 10 years with the total measurement less than 4 inches. This year the measurement for February to May is 3.78 inches. The years with the smallest measurements for the corresponding period are 1834 with 2.60 inches, 1857 with 2.76 inches, 1863 with 2.90 inches, and 1874 with 3.16 inches. Temperature throughout the past eight months was abnormally high, the mean for each month at Greenwich being above the average and the excess for the whole period 2.3°.

NEW BRAZILIAN METEOROLOGICAL ORGANIZATION.

Members of the Weather Bureau staff are in receipt of *Foreign Bulletin No. 1*, dated June 28, 1921, and signed by Dr. J. de Sampaio Ferraz, the new director of the Brazilian Meteorological Service. The following paragraphs, quoted from the *Bulletin*, will show the scope of the work contemplated by the new organization:

I have the honor of advising you that the "Directoria de Meteorologia Astronomia" of the Brazilian Department of Agriculture has been divided in two separate services, "Directoria de Meteorologia" and "Observatorio Nacional."

The new "Directoria de Meteorologia," which was placed under my direction, will continue the climatological work established in 1909, uniformizing methods of all meteorological activities in the country and publishing all available data of the last ten years. I hope to be able to put out nine yearly bulletins by the end of this year. The Directoria will also establish a forecast service for central and southern Brazil; an aerological service for the aviators and general progress of meteorological science, creating kite and pilot balloon stations; a special coast service for navigation; an agricultural meteorology service; a marine meteorological service; a special service of rains and floods, and the usual investigations in every department of meteorology, principally those which may lead us, possibly, to longer ranges in forecasting weather. The Directoria will strive to explore conditions over land and ocean, in and near Brazil, and do its best to present rapidly the results to every meteorological institute of the world, being very pleased to receive their suggestions and counsel. All information concerning the whole of Brazil will be promtply given with pleasure. Rio Grande do Sul, Minas Geraes, and S. Paulo continue with their State services but under the supervision of the Directoria. The Reclamation Service of semiarid northeastern Brazil will maintain their rain organization.

The Directoria will be able to attend to any foreign requests of data from these separate services.

* * * * *

Attention is called to the fact that the old "Directoria de Meteorologia da Marinha" does not exist any more. It was extinguished many years ago.

METEOROLOGICAL STATION ON NAVASSA ISLAND.

In cooperation with the Naval Radio Service a special meteorological station has been established by the Weather Bureau on Navassa Island, West Indies. Masters of vessels that pass near Navassa may have their ship barometers checked by a standard instrument upon wireless request to the naval radio station at that point

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C. F. TALMAN, Professor in Charge of Library.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JUNE, 1921.

By IRVING F. HAND, Temporarily in Charge.

[Solar Radiation Investigations Section, Washington, D. C., July 28, 1921.]

For a description of instruments and exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, 48:225.

From Table 1 it is seen that the solar radiation intensities averaged slightly above normal at all the stations, but most noticeably at Santa Fe.

TABLE 1.—*Solar radiation intensities during June, 1921.*

[Gram-calories per minute per square centimeter of normal surface.]

Date.	8 a.m. 75th meridian time.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon. Local mean solar time.
		Sun's zenith distance.									
		Air mass. A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
Washington, D. C.											
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
June 1	11.38			0.77	0.96	1.17					10.59
2	10.59					1.20					8.18
3	10.59				0.77	1.24	0.93	0.67	0.49		10.97
6	9.14		0.76	0.91	1.13	1.40					7.29
13	13.61						0.95				12.24
14	9.14						1.03				7.87
20	12.68		0.71	0.86	1.04	1.26					9.83
21	9.47				0.92	1.26					12.68
22	13.61				1.05						16.20
27	19.89		0.49	0.62	0.84	1.11					19.23
28	18.60		0.69	0.78	1.03	1.28					16.79
Means			0.66	0.79	0.97	1.24					
Departures			±0.00	+0.02	+0.06	−0.01					
Madison, Wis.											
June 4	6.02					1.44	1.19				6.02
11	17.96				1.10	1.35	1.08				9.83
17	18.59					1.16					17.96
28	15.62					1.25					16.18
Means					(1.10)	1.30	(1.14)				
Departures					−0.03	+0.00	+0.06				
Lincoln, Nebr.											
June 11	16.79			0.98	1.14	1.40	1.15	0.97	0.85		15.65
12	17.37		0.76	0.87							20.57
16	17.37			0.97	1.15	1.37					17.96
18	17.37			0.97	1.15	1.35		0.97	0.86		19.48
28	17.37			0.90	1.02	1.27					15.65
30	18.62			0.97	1.13	1.33					16.20
Means			(0.76)	0.93	1.12	1.34	(1.15)	(0.97)	(0.86)		
Departures			±0.00	+0.01	+0.03	−0.02	−0.05	+0.05	+0.08		
Santa Fe, N. Mex.											
June 8	7.29			1.15	1.24						7.87
10	5.79		0.93	1.11							8.18
11	6.27		1.06	1.18	1.33						9.83
16	8.18			1.25	1.38	1.56					6.76
17	6.50		1.14	1.22	1.36	1.47					7.57
21	5.79					1.54					9.14
22	6.50			1.17		1.55	1.34	1.13			8.48
23	5.56					1.55					7.57
24	7.04		1.06	1.20	1.35	1.52					5.79
25	7.57		0.99	1.13	1.26	1.49					7.87
29	7.29		1.06	1.12	1.19						10.59
Means			1.04	1.17	1.30	1.53	(1.34)	(1.13)			
Departures			+0.08	+0.09	+0.06	+0.06	+0.02	−0.03			

*Extrapolated.

Table 2 shows an excess in the amount of radiation received from the sun and sky at Washington during the second and third weeks, and a slight deficiency at the beginning and ending of the month. At Madison there was an excess during the first three weeks, and a deficiency during the last week. The deficiencies during the last week at both stations may be attributed, partly at least, to the period of haze which began during the latter part of June and which was very marked during the first week in July at Washington.

Skylight polarization measurements obtained at Washington on six days averaged 55 per cent with a maximum of 59 per cent on the third. Measurements obtained at Madison on three days averaged 65 per cent with a maximum of 67 per cent on the fourth. These are about average values for the respective stations for June.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning—	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
June 4	493	522		− 10	−19		−869	−5030	
11	617	541		+ 98	+22		−185	−4874	
18	636	598		+108	+64		+572	−4424	
25	482	511		− 44	−30		+263	−4034	

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE, MAY, 1921.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, Aug. 1, 1921.]

In continuation of preceding publications, I give in the following table the results obtained at Montezuma, near Calama, Chile, in May, 1921, for the solar constant of radiation. The reader is refered to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. P/ρ s. c.	Humidity. V. P.	Humidity. Rel. Hum.	Remarks.
1921.								
P. M.	cal.					c. m.	Per cent.	
May 3	1.938	$M_{1.42}$	S−	0.867	0.581	0.38	16	Cumuli over high peak.
	1.957	$M_{1.48}$						
	1.946	W. M.						
A. M. 4	1.952	$M_{1.38}$	S	.879	.664	.25	12	Cirri in east earlier in morning.
	1.948	$M_{1.51}$						
	1.950	W. M.						
P. M. 5	1.933	$M_{2.61}$	S−	.875	.459	.40	21	
6	1.952	$M_{1.36}$	S	.875	.558	.51	28	Small patches of clouds over high peaks.
	1.949	$M_{1.63}$						
	1.950	W. M.						
8	1.952	$M_{1.65}$	S	.879	.630	.33	12	
	1.958	$M_{1.46}$						
	1.955	W. M.						
9	1.938	$M_{1.76}$	S	.879	.634	.35	16	
	1.949	$M_{1.95}$						
	1.944	W. M.						
A. M. 14	1.938	$M_{1.94}$	S	.883	.682	.26	14	
	1.944	$M_{1.80}$						
	1.941	W. M.						
15	1.934	$M_{1.72}$	S	.883	.606	.21	9	
	1.941	$M_{1.62}$						
	1.937	W. M.						
P. M. 21	1.863	$M_{2.20}$	U+	.881	.613	.28	13	Cirri in various parts of sky.
	1.871	$M_{2.64}$						
	1.868	W. M.						
22	1.937	$M_{1.92}$	S	.875	.626	.19	8	Cirro-cumuli all around east.
	1.936	$M_{1.70}$						
	1.937	W. M.						
A. M. 23	1.933	$M_{1.66}$	S	.880	.701	.22	9	
	1.936	$M_{1.46}$						
	1.935	W. M.						
P. M. 24	1.963	$M_{1.84}$	S−	.881	.748	.20	6	
	1.958	$M_{1.49}$						
	1.960	W. M.						
A. M. 25	1.955	$M_{1.30}$	S	.885	.820	.13	4	
	1.946	$M_{1.39}$						
	1.950	W. M.						
28	1.941	$M_{1.41}$	S−	.871	.688	.18	8	Cirro-cumuli scattered about sky.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was very much higher than usual at land stations in the British Isles, while on the Atlantic and Gulf coasts of the United States, as well as in the West Indies, the Bermudas, and Azores, it was not far from the normal.

The number of days on which fog was observed was somewhat below the normal on the Banks of Newfoundland and above in the waters adjacent to the west coast of Ireland, while it was comparatively rare over the middle section of the steamer lanes.

June is ordinarily characterized by quiet weather, and, taking the ocean as a whole, the month under discussion was no exception to the general rule, although in the two 5-degree squares between latitudes 40° and 45° and longitudes 40° to 50° gales were reported on three days, which is considerably above the normal for that region. They were also observed on two days in the northwestern section of the Gulf of Mexico, due to the tropical disturbance that occurred in the last decade of the month, which will be referred to later.

From the 1st to the 5th moderate weather was the rule over practically the entire ocean, with fog over the Grand Banks on the 1st and 2d and in the vicinity of the British Isles on the 3d and 4th. The observer of the British S. S. *War Mehtar* stated that on the 1st, while off the southeast coast of Florida, excessive refraction was observed in the strongest part of the Gulf Stream, temperature of the air 80° F., water 79° F.

On the 6th there was a well-developed LOW of limited extent, central near latitude 39° N., longitude 62° W. It moved slowly eastward during the next 24 hours, gradually decreasing in intensity. Storm logs follow:

British S. S. *British Beacon:*

Gale began on the 5th, wind NNE.; lowest barometer 29.79 inches at 8 p. m. on the 6th; wind NE., 9; position, latitude 39° 52′ N., longitude 61° 36′ W. End of gale on the 7th. Highest force of wind 10, NE. Steady from NE.

American S. S. *Hattie Luckenbach:*

Gale began on the 6th, wind S.; lowest barometer 29.52 inches at 5 a. m. on the 7th; wind SSW.; position, latitude 40° 30′ N., longitude 56° 40′ W. End at noon on the 7th, wind NNW. Highest force 8, shifts SW.-NW. in sudden squalls.

On the 8th the British S. S. *Galtymore* experienced a westerly gale, as shown by the following storm log:

Gale began on the 8th, wind SW.; lowest barometer 29.57 inches at 1 a. m. on the 8th; wind SW., 7; position, latitude 53° 50′ N., longitude 57° 19′ W. End on the 8th, wind N. Highest force of wind 8, SW.; shifts, SW.-W.-NW.-N.

On the 9th westerly gales were encountered off the west coast of Scotland, and one storm log was received from a vessel in the western part of the steamer lanes, although moderate weather seemed to be the rule over the greater part of that region. Storm logs follow:

British S. S. *Lexington:*

Gale began on the 9th, wind SW.; lowest barometer 29.71 inches at noon on the 9th; wind W., 9, at Greenock, Scotland. End on the 10th. Highest force of wind, 11; steady from west.

American S. S. *Asquam:*

Gale began on the 9th, wind ENE.; lowest barometer 30.07 inches at 8 p. m. on the 9th; wind ENE., 9; position, latitude 40° 10′ N., longitude 53° W. End on the 10th, wind ENE. Highest force of wind 9, ENE. Steady from ENE.

On the 12th there was a disturbance central in the vicinity of the coast of Nova Scotia, moderate gales being reported in the easterly and southerly quadrants. Storm log follows:

Dutch S. S. *Westerdijk:*

Gale began on the 12th, wind SW.; lowest barometer 29.67 inches at 7 p. m. on the 12th; wind WSW., 6; position, latitude 40° 25′ N., longitude 65° 40′ W. End on the 12th, wind WSW. Highest force 8, WSW.; shifts WSW.-NW.

On the 14th a few vessels in the western section of the ocean recorded gales, although moderate weather prevailed for the most part.

On the 17th two vessels about 200 miles west of Swan Island reported easterly gales, although no storm logs were rendered.

The daily weather map for the 17th shows a slight depression in the southern part of the Gulf of Mexico, that afterwards developed into a severe tropical disturbance, as shown on Charts IX, X and XI for June 20, 21, and 22 respectively.

According to press reports this storm caused a great deal of damage along the Texas coast, at least six vessels being sunk, and a large number of other casualties also reported. The New York Maritime Register of July 6, published a very interesting account, taken from the Galveston News, of the experience of the American tanker *William H. Doheny*, Capt. Locke, during this gale.

This vessel left Galveston for Tampico in ballast on the afternoon of the 21st, sky overcast and wind moderate. About 10 p. m. on the 21st received a radio stating that there was a storm off the Rio Grande moving in a northwesterly direction. Barometer read 29.80 inches at that time and falling slowly, wind force 5 (direction not given). Everything was made ready for rough weather, and by midnight, when about 70 miles off Galveston, wind rose to force of 8, with heavy squalls and downpour of rain. The violence of the weather increased, and by 4 a. m. on the 22d it was raining so hard that it was impossible to see more than a ship's length, the force of the wind being 10. By 5:35 a. m. the force had increased to 11 or 12 from the ENE., with tremendous seas. Just at that time the propellor dropped off, leaving the ship to the mercy of the seas. The stream anchor was put out forward in 25 fathoms of water and the head of the ship brought into the wind. At 8 a. m. on the 22d the sea was far too heavy to anchor, as there would have been danger of the anchor chains parting. The rain still fell in torrents, and it was impossible to see more than a ship's length ahead, while the vessel was drifting toward the beach helpless. Suddenly, at about 10 a. m., the wind decreased in force, showing that the center of the hurricane was near, the barometer reading 28.93 inches. The vessel was in 10 fathoms of water with the wind shifting from east to west, and a rising barometer. It was a dead calm, the smoke from the stack rising straight up into the sky with now and then an irregular wave, while the air was filled with thousands of birds and insects caught in the whirl and unable to fight their way outside. The calm lasted only a short time, as by 10:20 the wind began to blow from the west, steadily increasing until it reached a force of 11. As it fortunately came from the west it blew the vessel off shore, saving her from being beached, as she undoubtedly would have been if she had not been in the direct center of the hurricane. Gradually the wind decreased, and at 7 p. m. the ship anchored in 17 fathoms

of water off Cavallo Pass; latitude 28° 10′ N., longitude 95° 56′ W., where she remained until towed into Galveston the next morning. Storm reports from other vessels follow:

American S. S. *Alabama:*

On the 20th, moderate to whole gale, rough sea, overcast and rain; vessel hove to. On the 21st moderate gale to fresh breeze, overcast and rain; hove to from 1 a. m. to 9 p. m. Position, 7 a. m., 20th, latitude 23° N., longitude 94° 40′ W.; 7 p. m., 21st, latitude 23° 10′ N., longitude 94° 15′ W.

American S. S. *Waxahachie:*

At 1 p. m., G. M. T., 22d, hurricane central near latitude 29° N., longitude 94° W. Highest force of wind 11, SE. Lowest barometer 29.60 inches.

On the 19th and 20th southerly gales prevailed over a limited area between the 35th and 45th parallels, and the 40th and 50th meridians. Storm logs follow:

British S. S. *Strathearn:*

Gale began on the 19th, wind SSE.; lowest barometer 29.68 inches at noon on the 19th, wind SSE., 8; position, latitude 43° 04′ N., longitude 43° 41′ W. End of gale on the 19th, wind S. Highest force of wind 8, SSE.; shifts SSE.-SSW.-SW.-S.

American S. S. *Editor:*

Gale began on the 19th; lowest barometer 29.79 inches at noon on the 20th, wind S., 8; position, latitude 44° 30′ N., longitude 40° 45′ W. End of gale on the 21st, wind WNW. Highest force of wind 8, S.; shifts S.-SW.-WSW.-WNW.

The observer on board the British S. S. *War Mehtar* states that at noon on the 22d, while at latitude 41° 35′ N., longitude 30° 51′ W., passed through tide rip extending in a north and south direction. Foam on outer edges. Temperature of air 76° F., water 69.5° F.

On the 23d moderate northerly gales were encountered over a small area between the 40th and 45th parallels and the 40th and 50th meridians. Storm log follows:

British S. S. *Aspinet:*

Gale began on the 22d, wind SSE.; lowest barometer 29.73 inches at 4 a. m. on the 23d, wind N., 5; position, latitude 42° 38′ N., longitude 44° 26′ W. End of gale on the 23d, wind NNW. Highest force 8, NNW.; shifts not given.

On the 24th and 25th moderate weather was general over the entire ocean, while on the 26th the conditions were similar, except that one vessel reported a moderate gale, as shown by the following storm log:

American S. S. *Steelmaker:*

Gale began on the 25th, wind SSW.; lowest barometer 29.90 inches at 7 p. m. on the 26th, wind SSW.; position, latitude 39° 51′ N., longitude 49° W. End at 8:50 p. m. on the 26th, wind NW.; highest force 8; shifts SSW.-NW.

During the remainder of the month only light to moderate winds were reported over the entire ocean.

The observer on board the American S. S. *Steelmaker* states that at 5:45 p. m. on the 28th, position, latitude 40° 04′ N., longitude 60° 38′ W., observed marked tide rip extending to NNW. and SSE. horizons in a straight line.

The observer on board the British S. S. *Antillian* reports that on the night of the 14th, latitude 52° 21′ N., longitude 6° W., he saw quite distinctly the flashing light on Bardsey Island, Wales; bearing 60° true, distance 55 miles.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

At Dutch Harbor pressure was below normal by some 0.30 inch during the first decade, above normal by about 0.12 inch during the second decade, and below by 0.36 inch during the last decade. At Honolulu it was below normal by 0.04 inch during the first and second decades and approximately normal in the last. At Midway Island it was below normal for the periods 1-5 and 12-17, by about 0.08 inch in each instance, and above normal on other days, the average plus departure being some 0.06 inch.

As will be seen these pressure departures indicate almost a normal degree of atmospheric fluctuation for June and offer very little in the way of explanation for the heat wave which broke upon several continental areas toward the end of the month.

So far as known no typhoons occurred during the month, although it is possible that the one which struck Manila on July 5 may have been in existence at the end of June.

At the beginning of the month a moderate depression was central near the Bonin Islands. During the 2d and 3d it moved slowly north-northeastward and developed somewhat, causing northerly to easterly gales to the east of the Japanese Islands. It disappeared in the direction of Bering Sea on the 5th.

The American four-masted bark, *Moshula*, Capt. F. O. Parker, Manila for San Francisco, encountered this gale on the 3d in latitude 39° 04′ N., longitude 155° 25′ E. The wind set in from ESE. and backed to NE.; highest force 10; barometer at noon of 3d, 29.37 inches. The *Moshula* lost her fore lower topsail, mizzen upper topsail, and jib in this gale.[1]

This depression was followed by another of moderate character which caused a fresh easterly gale in the Yellow Sea on the 4th. The latter depression does not appear to have developed.

On the 5th there were evidences of a large but rather shallow depression between Dutch Harbor and Midway Island. By the following day it had developed somewhat to the northeastward with barometer readings as low as 29.16 inches in the southern part of the Gulf of Alaska accompanied by a fresh SE. gale. This depression moved very slowly and still covered the same waters on the 12th. On the 13th, however, it moved inland on the British Columbian coast, in advance of the rising pressure in the region of the Aleutians.

The Japanese S. S. *Suwa Maru*, Capt. M. Machida, Yokohama (May 28) for Seattle, had this gale from the 6th to 8th. Second Officer and Observer, S. Mitomi, furnishes the following report:

Gale began on the 6th, wind SW.; lowest barometer, 29.16 inches at 6 a. m., same date, in latitude 51° 55′ N., longitude 145° 30′ W.; end of gale on the 8th, wind SE.; highest force, 9, SE.

Prior to the passing of this depression the North Pacific anticyclone had not attained the normal development for June. Its crest during this month is located in about latitude 37° N., longitude 147° W., with a central isobar of 30.25 inches. Up to the 13th, there was only a weak anticyclone between the Hawaiian Islands and the Lower California Peninsula. With the passing of the depression just referred to, however, this area was reinforced by the rising pressure over the Aleutians, thereby causing the center to shift to the northwestward to about the usual position, where it remained to the end of the month.

During the last half of the month two moderate depressions moved slowly across the northern part of the ocean. The first of these was in evidence to the southward of Japan on the 15th, whence it moved northeastward to the region of the Aleutians by the 21st.

[1] Further particulars regarding the report of this vessel will be found on page 360.

The second depression followed in about the same track. On the 21st it was central to the southward of Japan, and was causing a strong ENE. gale along the coast in the vicinity of Yokohama.

The British S. S. *Robert Dollar*, Capt. M. Ridley, Seattle, for Kobe, experienced this gale on the 21st when off Oshima. Observer M. M. Blackadder has furnished the following report:

Gale began on the 21st, wind ENE.; lowest barometer 29.55 inches at 2 p. m. same date, in latitude 33° 40′ N., longitude 136° 30′ E.; end of gale on 22d, wind NE. by E.; highest force, 9, ENE.

By the 29th the depression had moved to the western part of the Gulf of Alaska and a moderate to fresh gale was blowing on its southern edge. The Japanese S. S. *Mandasan Maru*, Capt. R. Watanabe, Yokohama for San Francisco, had this gale on the 29th and 30th. Following is the report from this vessel:

Gale began on the 28th, wind W. by S.; lowest barometer 29.51 inches at 8 a. m., same date, in latitude 47° 46′ N., longitude 164° 15′ W.; end of gale on 30th, wind W.; highest force, 8 W.; shifts, 2 points.

From the 20th until the end of the month pressure continued low near the Aleutians and a series of weak depressions moved thence over Alaska and the British Northwest Territories.

A waterspout was observed from the British S. S. *Eastern Prince* on June 29. This vessel, under command of Capt. E. Naylor, was proceeding southward along the west coast of Central America at the time. Second Officer and Observer T. R. Jones states that between 8:30 a. m. and 9 a. m. (A. T. S.), when in approximately latitude 8° 38′ N., longitude 88° 58 W., a waterspout formed at a distance of some 8 to 10 miles from the vessel, in a WNW. direction. It traveled in a westerly direction. The sky was overcast at the time and a heavy rain falling; lightning and thunder occurred later; the wind force was between 1 and 2, Beaufort.

Fog was reported on numerous occasions during the month.

WEATHER LOG OF AMERICAN BARK "MOSHULA."

Among the vessel weather reports received recently by the Weather Bureau was one strongly suggestive of the days before steam power had so largely supplanted sail on the oceans. This report was from Capt. F. O. Parker, of the American four-masted bark *Moshula*, United States Shipping Board, and covered a voyage from Newcastle (Australia) via Manila to San Francisco. The *Moshula* sailed from Newcastle, with a cargo of 5,050 tons of coal, on November 12, 1920, and arrived at Manila January 10, 1921, being 57 days at sea and covering a distance of some 7,306 miles. Sailing from Manila on May 3, she arrived at San Francisco on July 4, 63 days. Distance sailed, approximately 7,681 miles.

In addition to the valuable meteorological data contained in the report, numerous entries under the head of "Remarks" lend an intimate touch not usually found in reports of the present day. The following notes are taken at random from this part of Capt. Parker's report:

December 8: 7 a. m., heavy cloudburst, filled all tanks. This was in latitude 1° 51′ S., longitude 163° 10′ E.

December 16: 5° 02′ N., 160° 51′ E. Heavy squalls (ESE.); main royal blown away.

December 24: 17° 11′ N., 143° 08′ E. Heavy swell from SW. Hard squalls; lower top gallant, flying jib and mizzen upper topsail blown away.

January 7: Noon, Corregedor bearing E.-N., 15 miles. Making four-hour tacks; beat 20 miles dead to windward in 24 hours; has 5,000 tons of coal on board and has been one year out of dock.

May 3: Manila Bay, 6 p. m. Set sail, hove up anchor and proceeded down the Bay. Midnight, Corregedor Light abeam; North Channel, fine clear weather.

June 2: 37° 03′ N., 155° 44′ E. Heavy gale from E. to NE.; blew away fore lower topsail, mizzen upper topsail and jib; wind shifted from ESE. to NE. in gale.

July 5: Off Farallones; tug *Sea Wolf* took us in tow and anchored off Meig's Wharf at 5:30 p. m.

The *Moshula* "crossed the line" on December 9, in longitude 163° 26′ E. During the eight days preceding the average run was 50 miles and for the eight days following, 65 miles. The daily average for the entire voyage was about 125 miles. The best day's run was on June 23–24, when on an E. course in a moderate SW. gale the *Moshula* logged 251 miles.

WEATHER OF THE NORTH INDIAN OCEAN.

Capt. Charles Olson of the American S. S. *Easterling* has submitted the following note regarding the weather experienced in the Indian Ocean during the period May 17 to June 1, 1921:

We passed Ujung Tapa Gaga Light 8:40 p. m. on the 17th. Sea and breeze moderate. The breeze freshened with a rough sea on the 20th and we experienced an ENE. set of ½ knot for the preceding day; squalls and heavy clouds all the way. Moderate seas and westerly winds on the south and west of Ceylon.

Arrived at Colombo on the afternoon of the 22d and sailed in the evening of the 23d.

From Colombo to Minikoi the sea and winds were moderate. We experienced a very heavy rainstorm 30 miles SE. of Minikoi.

The course was then set for Ras Hafin (on the 25th), winds westerly, sea moderate, and the weather fine with occasional squalls to latitude 9° 50′ N., longitude 60° 00′ E., where the SW. wind with a force of 4 to 6 had caused a rough sea. At noon of the 29th in this position changed the course to go north of Sokotra. The set for the preceding day was NW., 0.8 knot. The SW. monsoon was blowing strong then and continued so with overcast sky and high seas until we passed 40 miles north of Sokotra on the night of May 31 and June 1.

After passing Sokotra the SW. monsoon came in again, blowing with moderate force and a moderate sea which gradually decreased as we neared the Red Sea.

GALE OFF CAPE OF GOOD HOPE.

The American S. S. *Hampton Roads*, Capt. S. W. Pine, Durban for Key West, experienced heavy weather June 15–17, when rounding Cape of Good Hope. Second Officer and Observer E. Walker has submitted the following report:

Gale began on the 15th, the wind backing through N. to NW. reaching force 8 in squalls. Position of ship at noon (G. M. T.), latitude 34° 42′ S., longitude 24° 21′ E. At noon on the 16th the wind shifted to W. force 10, and at 4 p. m. increased to force 11. This was the height of the gale and the lowest barometer, 29.60 inches, occurred at this time. There were heavy passing squalls with rain and hail and lightning all around the horizon. Sea rough and choppy. On the 17th the wind shifted to NW., decreasing to force 9, with a rising barometer. At 8 a. m. of the 18th the wind was NW., 5, with a moderate sea; barometer 30.11 inches; position, 34° 30′ S., 16° 20′ E.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

North Atlantic.—The Atlantic Ice Patrol reports that ice conditions in the north Atlantic are worse than they have been for many years, large numbers of icebergs being scattered over a wide area.[1]

British Isles.—The month was again one of widespread deficiency of rainfall, less than half the average falling everywhere except in the north and west of Scotland and in Queens County. * * *

The general rainfall for June, expressed as a percentage of the average, was: England and Wales, 17; Scotland, 40; Ireland, 24.[1]—[Cf. this REVIEW, p. 353.]

France.—The prolonged dry spell in France, following an unusually dry winter, is causing anxiety as to crops and cattle.[1]

Switzerland.—Switzerland has also experienced a hot, dry month, the rivers being 6 feet lower than usual, but falls of snow at altitudes above 4,500 feet have been reported.[1]

British Honduras.—The Belize district of British Honduras was suffering from severe drought, but floods following a heavy storm were reported from San Salvador on the 11th.[1]

Egypt.—Serious floods following heavy rainfall have affected the cotton and wheat crops in the northeastern part of the Egyptian delta.[1]

India.—The Indian monsoon broke later than usual this year, but by the 22d of the month it was extending normally, with excess of rain in some regions.[1]

[1] *The Meteorological Magazine*, July, 1921, pp. 171-172.

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

GENERAL CONDITIONS.

By A. J. HENRY.

In general, high temperature over the greater portion of the United States, which has now featured the weather since September, 1920, continued during the month and was associated with a growing deficit in precipitation, more particularly from the east Gulf States northward to the border. The only extensive area with precipitation above normal was in the States of Texas, New Mexico, and Colorado. The prominent phenomena, temporary in character, were the disastrous flood in the Arkansas and Fountain Rivers in the vicinity of Pueblo, Colo.; the large discharge of the lower Colorado River at Yuma, Ariz.; and the tropical storm which after pursuing an unusual path dissipated over northern Texas on the 24th.

The usual details follow:

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

Low-pressure areas were generally unimportant and few could be identified from day to day as distinct disturbances. The one exception, and also the feature of the month, was the hurricane (No. VII on the chart), which struck the Texas coast on the afternoon of the 22d. Though of small diameter this storm had all the characteristics of the type and the pressure gradients, as the storm passed inland indicated a very low barometer reading at the center. Houston, Tex., which was some distance east of the storm center as it passed northward, reported a minimum barometer reading of 29.37 inches and a 60-mile gale and this after the storm had moved fully 75 miles inland from Matagorda Bay, Tex. High-pressure areas were but weakly developed. The hurricane mentioned above, and another low-pressure area of tropical origin, are not included in the tables below.

LOWS.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
June, 1921	3.0	......	......	......	3.0	......	......	1.0	......	7.0
Average number, 1892-1912, inclusive	3.3	0.8	0.4	0.7	1.2	0.4	0.2	0.3	1.1	8.4

HIGHS.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain Region.	Hudson Bay.	Total.
June, 1921	2.0	....	2.0	1.0	1.0	6.0
Average number, 1892-1912, inclusive	1.7	0.6	1.9	0.9	0.5	5.6

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Aug. 1, 1921.]

PRESSURE AND WINDS.

The pressure distribution for the month as a whole was not materially different from that usual for June, except that the monthly averages were slightly higher than normal from the lake region and Ohio Valley westward to the Rocky Mountains, and usually lower than normal along the Atlantic and Pacific coasts and generally over the southern districts.

An important high pressure area central over the upper Lakes at the beginning of the month drifted eastward to the Atlantic coast within the following day or two. This was quickly followed by a second one that entered the northwestern districts on the morning of the 3d, which, like the one preceding, advanced slowly eastward along the northern border, reaching the Atlantic Coast by the end of the first week, where it gradually drifted southward and finally merged with the general high-pressure area normal at that period of the year over the Southeastern States and the adjacent portions of the Middle Atlantic. No other important high areas developed during the month, although pressure remained relatively high over the Southeastern States during much of the month with a resultant drift of the warm air of that region northward and northwestward.

Low areas, as is usually the case during the warmer months of the year, were without material force and pursued indefinite courses.

Under the influence of a moderate decrease of pressure from southern to northern districts, between the Rocky Mountains and the Atlantic coast, the general drift of the atmosphere was in the same direction and warm southerly winds prevailed over nearly all districts from

the Gulf of Mexico and Rio Grande Valley to the Canadian boundary. They were likewise southerly over much of the Rocky Mountains and locally in the Plateau region. On the Pacific coast the winds were mostly from points between the Northwest and Southwest.

High winds were notably absent over large areas. Local high winds occurred in connection with thunderstorms, but these usually covered but small areas. A list of the most important storms of this character follows near the end of this section.

TEMPERATURE.

June, 1921, was a month of unusually small variations in temperature; this being particularly in evidence over the great central valleys and northern districts, where, after the first few days, the temperature remained persistently high throughout the month.

Under the influence of fairly high barometric pressure over the Great Lakes and eastward to New England, the first week had temperatures below normal over the northern districts from the Dakotas eastward, and along the Atlantic coast. This period was likewise cooler than normal over most of the Rocky Mountain and Plateau regions. In the Ohio and lower Mississippi Valleys, and over the west Gulf States and portions of the southern Plains the first week was mainly warmer than normal and over a considerable area in the far Northwest similar conditions prevailed.

With the passage eastward of the high-pressure area, referred to above, pressure became low over the interior districts while over the Southeastern States and the adjacent ocean the summer type of high pressure began to develop. Under this combination warm weather set in over the greater part of the country, and the second week was warmer than normal in all districts save in the southern Plains and adjacent Southwest. In the plateau region the week was one of unusual warmth and it was nearly as warm over all northern and central districts to the eastward.

The pressure distribution favored the combination of warm weather over the central valleys during the third week of the month, but lower temperatures prevailed in the more Northeastern States and decidedly cooler weather prevailed from the Rocky Mountains westward.

During the final decade of the month temperature continued high over all portions of the country, save in the region between the lower Mississippi Valley and the Rocky Mountains, where the influence of lower pressure attending the tropical hurricane that entered the west Gulf district early in the decade favored northerly winds and cooler weather, the average temperature for the period ranging from 3° to 6° below normal.

For the month, as a whole, weather warmer than normal prevailed to an unusual extent. In eastern Tennessee and portions of adjacent States the daily temperatures were above normal continuously throughout the month, and over many other interior sections there were frequently only a few days near the beginning of the month that were cooler than normal. In portions of the upper lake region and thence westward to the middle Missouri Valley it was the warmest June in the history of the Weather Bureau.

The tendency to an excess of warmth during the present year continued during June undiminished over the interior portions of the country, in fact this condition extends back in certain localities beyond the beginning of the year, notably in portions of Illinois where for 10 consecutive months the mean temperatures have averaged higher than normal by substantial amounts, the average excess for the entire period amounting in some cases to more than 5° per day, exceeding any previous period of continued warmth in 50 years or more.

Over a small area embracing western Texas, the greater part of New Mexico, and portions of Utah and Colorado, the average temperature for the month was below the normal. Elsewhere the averages were practically everywhere above.

Maximum temperature of 100° or higher were reported at some period during the month from all the States save New England and New York, the highest reported 120° occurring in southern California. Although high temperatures prevailed continuously for longer periods than usual during June in many localities, they were in few if any cases higher than have occurred in the same month of other years.

Occasional hot winds were reported from the Great Plains region; the most notable occurring in the vicinity of Ardmore on the night of the 28th–29th. A self-recording thermometer at the experiment farm showed a rise of 12°, from 80° to 92°, between 11 p. m. and midnight. No such high night temperature had ever been observed previously at that place.

The lowest temperatures were usually observed during the first week of the month, although in portions of the plateau region the coldest weather of the month was about the 15th to 18th, where light frosts occurred at numerous points at the lower elevations, and temperatures as low as 20° were reported from the higher and more exposed localities.

Freezing weather occurred early in the month at points in all the northern border States and temperatures as low as 20° were reported from several mountain States of the West.

PRECIPITATION.

The rainfall during the month was on the whole poorly distributed through the several weeks and exhibited the usual variations at near-by points common to the period of greatest thunderstorm activity. Such precipitation as occurred was mostly associated with thundershowers, often falling heavily for short periods, causing excessive run-off, and damage to fields and crops.

Early in the month heavy rains occurred over the eastern slopes of the central Rocky Mountains, particularly in eastern Colorado and northern New Mexico. Falls of 2 inches in 24 hours were common, and totals of 10 inches or more in the period from the 3d to 7th were authoritatively reported from several places. The fall was notably heavy in the region embracing the headwaters of the Arkansas, above Pueblo, Colo., and caused one of the worst floods ever known at that place, resulting in large loss of life and immense damage to property. A full account of this storm appears in this REVIEW as a contribution by the River and Flood Division. (Cf. pp. 366–367.)

In addition to the area referred to above, the rainfall during the first week extended over much of the Plains region from the central portion of Texas and New Mexico northward into western Nebraska and eastern Wyoming, the amounts over large areas ranging from 2 to 4 inches or more. In other districts precipitation during the first week was mostly light and no appreciable amounts occurred over many. The second week had substantial rains somewhat to eastward of the area of heavy rains referred to above and extending generally from the Rio Grande Valley, and west Gulf States northward into Wisconsin and Minnesota. Over districts to

eastward of the Mississippi River there was usually little effective rainfall and practically none from the western Plains region to the Pacific coast.

The third week of the month had good rains over much of the great spring wheat district and there was considerable precipitation for a week in summer over the far Northwest. Good rains occurred over a rather narrow area from the panhandle of Texas northeastward to Lake Superior, and beneficial showers occurred locally in Illinois and portions of adjacent States, and showers were rather general in the upper Ohio Valley, the northern portions of the Gulf States, and locally in the South Atlantic Coast States.

The final decade of the month had liberal rains from eastern and central Texas northward into the upper Mississippi Valley, and thence into the region of the Great Lakes, resulting mostly from the tropical storm that entered eastern Texas early in the decade and moved slowly northward. Local showers were reported from points in the east Gulf and South Atlantic States and showers were widespread over eastern districts as the month closed. In the western Great Plains and thence to the Pacific coast little precipitation occurred during the last decade, and the need of more moisture was beginning to be seriously felt over large areas at the close of the month.

From the Mississippi River eastward the monthly precipitation was nearly everywhere less than normal, the deficiency being particularly large in the east Gulf and South Atlantic States. There was also usually less than normal in the region from the Rocky Mountains westward. From the Mississippi River westward to the Rocky Mountains, and to the southward of Iowa and Nebraska, the precipitation was nearly everywhere greater than the amounts usually received in June, the excesses being unusually large in Oklahoma, Texas, and New Mexico.

SNOWFALL.

Traces of snow were reported on different dates locally in the mountain regions of the West. In northern Nevada unusually heavy snow occurred on the 16th. At Winnemucca that reaching the ground melted mostly as it fell, but the accumulation on vegetation was sufficient to bend and break trees and their branches. In the higher elevations the depth on the ground and damage to trees and vegetation was much greater.

HUMIDITY.

In the central and southern Rocky Mountain States and thence eastward to the Mississippi River, the heavy rainfall during the month is clearly indicated by the high percentages of relative humidity, the excess amounting to 20 per cent or more in some cases. Over most other sections of the country there was a general deficiency, which was quite pronounced over the east Gulf and Atlantic Coast States.

SEVERE LOCAL STORMS.

In order to save space an effort has been made to condense the reports on severe local storms into a table as below. Much of the information it is desired to give is not available and time does not permit obtaining the data by correspondence. The authority for the several items in the table is given on the right.

It is obvious that the tabulation does not include all of the severe local storms which occurred during the month, but merely those which have so far come to the attention of the Bureau.

More complete tables will appear later in the Annual Report of the Chief of Weather Bureau.

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
Pueblo, Colo. (near)	2		2,640		$9,000	Hail		Official U. S. Weather Bureau.
East Las Vegas, N. Mex.	3					do	Much poultry and small live stock killed	Washington (D. C.) Star.
Abilene, Tex. (7 miles NW. of).	7		1,760		1,500	Small tornado		Official U. S. Weather Bureau.
Sangamon County, Ill.	14	p. m.		1		Electrical	Much damage from lightning and floods	Springfield State Journal.
Vance County, N. C.	14	p. m.	5,280			Hail and rain	Crops and vegetation destroyed	Henderson Daily Despatch.
Ellendale, N. Dak. (15 miles E.-SE. of).	18	2:30 p. m.				Tornado	Number houses and buildings destroyed	Official U. S. Weather Bureau.
St. Louis, Mo.	20			2		Electrical	Damage to buildings, trees, etc.	St. Louis Post-Despatch.
Outagamie and Shawano Counties, Wis.	20				30,000	Tornado		Milwaukee Daily Journal.
Detroit, Mich.	21					Electrical	Cloud-burst	Detroit Free Press and Detroit Journal.
Do	22			1		do	One death by lightning	Detroit Free Press.
Cass County, Tex.	23	p. m.			200,000	Tornado		Dallas Morning News.
Barnesboro, Pa.	23	p. m.			(?)	Wind	Theater destroyed	New York Sun.
Lewiston, Idaho (SW. of)	23				500,000	Hail	Loss to fruit interests	Official U. S. Weather Bureau.
Walla Walla, Wash.	23					Hail and wind		Do.
Washington County, Md.	26					Wind and rain		Washington (D. C.) Post.
Arlington, Va.	26					Electrical	Lightning struck Navy radio tower	New York Times.
Gillette, Wyo.	27	10 p. m.	2,640			Hail	Crops, vegetation, and windows suffered	Sheridan Post.
Trenton, N. J.	27-28					Thunderstorm		New York Herald and New York Tribune.
New York City	28	p. m.				Rain and hail	Damage to truck farms on Staten and Long Islands.	New York Herald.
Davidson, N. C.	28	p. m.				Wind	Buildings and trees blown down; other damage.	Charlotte Observer.
Laurel, Del.	28					do	Lightning struck barn, killed horse and shocked several people.	New York Times.
Greenwich, Conn.	29	p. m.			30,000	Electrical		Do.

STORMS AND WARNINGS—WEATHER AND CROPS.

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

On the morning of June 1 pressure was low and falling over the eastern Gulf of Mexico and the northwestern Caribbean Sea, with a disturbance of slight intensity central over the latter region, and advisory warnings were issued daily until the 4th when the disturbance apparently filled up.

At 10:30 a. m. of the 16th the following advisory warning was issued:

> Disturbance of moderate intensity over western Caribbean Sea central near coast of Honduras southwest of Swan Island this morning apparently moving slowly northwestward will be attended by fresh and strong shifting winds and rains in northwestern Caribbean Sea next 36 hours.

By the morning of the 17th the disturbance had increased somewhat in intensity and an advisory warning of strong shifting winds and probably gales was issued for the northwestern Caribbean Sea and the Yucatan Channel. During the following night the disturbance passed inland over British Honduras in the vicinity of Belize, continuing its slow northwestward movement, and a maximum wind velocity of 52 miles an hour from the southeast was registered at Progresso, Yucatan, as the storm entered the southwestern Gulf of Mexico during the early morning of the 19th.

No further reports were received giving the approximate location of the storm until the afternoon and evening of the 21st when it was central off the mouth of the Rio Grande. The warnings issued on the 21st and the morning of the 22d are noted below.

A delayed radio report from the S. S. *Sucrosa* (received during the afternoon of the 22d) showed a barometer reading of 29.28 inches and a wind velocity of about 75 miles an hour from the southeast at 10 p. m. of the 21st in latitude 26° 30′ N. and longitude 95° W.

During the night of the 21st–22d the storm caused a a maximum wind velocity of 68 miles an hour from the northeast at Corpus Christi and a strong northeast gale and high sea at Point Isabel, and by 8 a. m. of the 22d the wind was blowing 42 miles an hour from the east at Galveston, with rising tide. Special observations at 10 a. m. showed rising pressure at Corpus Christi and slowly falling pressure at Galveston and Houston, and the following bulletin was issued at 12 noon:

> Tropical storm apparently moving inland over Texas coast vicinity Matagorda Bay. No further danger Corpus Christi southward.

At 5:30 p. m. the following bulletin was issued:

> Tropical storm central southwest of Houston moving northward, Gales along Texas coast east of Matagorda Bay will diminish to-night,

The hurricane warnings were ordered down at 9:30 p. m.

The wind reached a velocity of 60 miles an hour from the southeast at both Galveston and Houston, and the lowest barometer reading at a land station was 29.37 inches at Houston at 5:40 p. m. of the 22d. The storm continued to move slowly northward, with diminishing intensity, over the eastern portions of Texas, Oklahoma, and Kansas, thence northeastward over the Lake region.

Another disturbance was apparently forming on the morning of the 24th over the northwestern Caribbean Sea in the vicinity of Swan Island whence it moved slowly westward over southern British Honduras and Guatemala and by the morning of the 28th it was causing strong shifting winds and heavy rains over the southwestern Gulf of Mexico and also in the Gulf of Tehuantepec on the Pacific side. Advisory warnings were issued daily, based on delayed Mexican reports, until the 29th when the disturbance had apparently moved inland over Mexico. This disturbance was of much wider extent than the preceding one, but it apparently did not develop into a severe storm.

No storm warnings were issued during the month for the Great Lakes or the Atlantic and east Gulf coasts.

Frost warnings were issued for limited areas in the upper Lake region and the northeastern States on several dates during the first week of the month.—*Charles L. Mitchell.*

CHICAGO FORECAST DISTRICT.

No general warnings of any character were issued during the month in the Chicago forecast district.

However, frost warnings were sent to North Dakota points on the 2d and on the 3d to the lowlands of Wisconsin and Minnesota. On the latter date special warnings were sent to the Wisconsin cranberry marshes covering the ensuing two nights, the warnings being repeated to the marshes again on the 4th.

All the frost warnings were verified, except those issued on the 2d were only partly verified.

The advices sent to the cranberry marshes were especially beneficial, and the cranberry growers have expressed their great appreciation of the service.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

A tropical storm which had traveled from the Caribbean Sea across Honduras and southern Yucatan and thence northward through the Gulf of Mexico moved inland on the Texas coast, with its center passing near Matagorda Bay during June 22, 1921. Small-craft warnings were displayed on the Texas coast 9:30 a. m. on the 20th in anticipation of increasing winds. A 4 p. m. special observation from Brownsville, Tex., June 21, showed a fall in pressure of about 0.08 inch since 8 a. m., with rain falling; small-craft warnings were ordered for the Texas coast, 4 p. m., from Velasco to Brownsville. A 4:40 p. m. observation from Corpus Christi, Tex., showed a somewhat higher barometer than at 8 a. m., but the wind, 48 miles from the northeast, with heavy rain, and the tide high at Point Isabel and a storm tide of 4 feet at Corpus Christi Pass, indicated that the storm was moving toward the Texas coast, and the following warning was issued for the Texas coast, Port Arthur to Brownsville:

> NEW ORLEANS, LA., *June 21, 1921.*
>
> Hoist northeast storm warning, Texas coast 4:30 p. m. Disturbance apparently off mouth of Rio Grande, moving northeast; will cause increasing northeast winds and gales and rising tides.
>
> CLINE.

The following storm bulletin from the central office was distributed to all authorized addresses at 9:40 p. m.:

> WASHINGTON, D. C., *June 21, 1921.*
>
> Storm bulletin: Storm of unknown intensity central off mouth of Rio Grande apparently moving north-northwestward. Shifting gales to-night north to mouth of Colorado River and probably as far as Galveston. Every precaution should be taken. Advise all interests.
>
> MITCHELL.

Hurricane warnings were distributed at 9:25 a. m. on the morning of the 22d, as follows:

Washington, D. C., *June 22, 1921.*

Hoist hurricane warning 9:30 a. m., Texas coast, Matagorda Bay to Port Arthur, Tex. Tropical storm central off Texas coast east of Corpus Christi apparently moving northward increasing in intensity; it will cause dangerous shifting gales to-day along the Texas coast between Corpus Christi and Port Arthur.

Mitchell.

Northeast storm warnings were issued for the southwestern portion of Louisiana and the following wind forecast was sent to all stations on the Louisiana coast: "Increasing easterly winds Wednesday afternoon and night; dangerous tides on the coast"; signed, "Cline."

The following wind forecast was telegraphed with the forecast to all authorized points in southeastern Texas:

Strong northeast winds and gales in southeastern portion of Texas this afternoon and to-night, becoming northerly and westerly Thursday and subsiding. High tides on the east coast.

Cline.

No storms occurred without warning.—*I. M. Cline.*

DENVER FORECAST DISTRICT.

The outstanding feature of the weather for June was an area of high pressure which appeared over Alberta on the 1st and which had covered the northeastern Rocky Mountain slope by the morning of the 2d. This HIGH, in conjunction with a LOW that developed about the same time over the Rocky Mountain Plateau, was the cause of showers long the eastern slope from the night of the 1st–2d to the night of the 5th–6th, during which time some of the heaviest rains of record fell on the eastern slope of the Continental Divide in Colorado and in northern and eastern New Mexico. Especially heavy local downpours occurred over the Arkansas drainage basin above Pueblo during the afternoon and evening of the 3d and were followed by the disastrous flood at that city, although the rainfall was everywhere sufficient to raise the smaller streams of the eastern slope to the flood stage.

Twenty-four hour amounts of precipitation of more than 2 inches were common from Boulder County southward to Pueblo and the eastern portion of Fremont Counties on the 3d and 4th. It appears that the heaviest rains occurred from Penrose to Pueblo, including the drainage areas of Pecks, Rock and Boggs Creeks, and probably from Fountain to Pueblo. Although there are few reliable data for this region, the fact that the total rainfall exceeded 10 inches at a few places during the period from the 3d to the 7th seems to have been fairly well established.

The HIGH already referred to was followed on the 6th by another and more moderate area of high pressure on the eastern slope and in the upper Missouri Valley, the showers continuing in the same territory through the 7th, although the rainfall was much lighter.

An area of low pressure developed on the Rocky Mountain Plateau on the 10th and was attended by high temperatures until the 14th, causing a rapid melting of the more than usual amount of snow which remained at the higher elevations and producing exceptionally high stages in the streams of western Colorado, northwestern New Mexico and eastern Utah.

The usual summer distribution of air pressure prevailed during the latter half of the month. High temperatures in most of the Denver district from the 27th to the 30th resulted from extensive LOWS which covered about all of the Rocky Mountain region and western Canada.

Freezing temperature was forecast for extreme southwestern Colorado, extreme northwestern New Mexico, north central and extreme northeastern Arizona, and the higher elevations of extreme southeastern Utah on the morning of the 1st. Minimum temperatures of 30° and 36° were recorded at Flagstaff and Durango, respectively, on the following morning. Freezing temperature was also forecast on the morning of the 18th for the higher elevations of northern Arizona. The reading of the minimum thermometer at Flagstaff on the morning of the 19th was 30°. A temperature of 30° occurred at Flagstaff on the morning of the 18th for which no prediction was issued.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT.

The month was marked by a large number of rainy days in western Washington, but in other portions of the district neither the amounts of rainfall nor the number of rainy days were more than usual. Storms from the North Pacific passed inland at a high latitude and their influence was confined to the extreme northwest portion of the district.

Three well-defined depressions formed over the interior of California and the southern plateau: The first in the early part of the second decade, the second in the first part of the third decade, and the third near the close of the month. The first gave showers over a large portion of the district; the second caused many thunderstorms in the mountain sections but little or no rain fell at the regular stations; and the third gave rain in the North Pacific States extending south along the coast to Point Reyes. A secondary depression from a storm over the Northern Plains States developed over the southern plateau on the 15th, and moved rapidly southeast followed by an area of high pressure from the northwest. This movement caused a sharp fall in temperature in Nevada on the 16th, with heavy to killing frosts on the mornings of the 16th and 17th.

Fire-weather warnings were issued in northern California on the 9th and 21st. The first read, "Very warm weather with moderate hot drying northerly winds for the next two or three days." The second, "Thunderstorms this afternoon and to-night in the mountains with cooler weather." Both of these warnings were timely and fully verified.

The following commendation was received from the Signal Corps meteorologist, at March Field (near Riverside, Calif.):

The forecasts are appreciated at this field and they have come to prepare for things according to what the forecast is, and it is always correct.

No storm warnings were ordered during the month.—*G. H. Willson.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

[Weather Bureau, Washington, July 26, 1921.]

No serious floods occurred during the month except in the rivers having their sources in the Rocky Mountains. Many of these latter floods were by far the most disastrous in the recorded history of their respective localities, and at Pueblo, Colo., the stage of 24.66 feet between 1 a. m. and 2 a. m., June 4, was 12.36 feet above the previous high-water record of August 5, 1902.

According to the report of the United States Reclamation Service, 120 persons lost their lives through the flood, 70 at Pueblo, 12 at points above, and 38 at points below. At the time of writing this report, 143 persons were unaccounted for. The loss and damage amounted to at least $25,000,000. Detailed reports of this and other Rocky Mountain floods will be given later.

Atlantic and east Gulf drainage.—No floods.

Mississippi drainage.—Moderate floods without damage of consequence occurred during the closing days of the month in the Missouri River at Blair, Nebr., and below Waverly, Mo. Warnings were issued on June 27 and 28, and the water passed slightly above the flood stage at a few places.

That portion of the flood waters from the Rocky Mountain region that moved eastward caused general flood stages and overflows in the Arkansas River in Kansas and Oklahoma, and in the North Canadian River. Warnings were issued well in advance and the crest stages reached were from a fraction of a foot to nearly 3 feet above the flood stage.

Heavy rains over Oklahoma and Arkansas during the third decade of the month caused another decided rise in the Neosho and lower Arkansas Rivers, although flood stages were not quite reached in the Arkansas River. Timely warnings were issued and the total loss reported was $5,000 to corn and garden truck. Value of property saved through warnings about $5,000. Some other local crop damage was not reported in detail.

The heavy rains of June 22–25, over the drainage basin of the Red River caused rapid rises both in the main streams and its tributaries, although flood stages occurred only in the Sulphur River. Warnings were first issued on June 25, the river rising to from 5 to 10 feet above the flood stage, and at Ringo Crossing, Tex., the stage of 30 feet on June 27 was the highest of record. Flood loss, mainly to crops, amounted to more than $100,000, while property to the value of $15,000 was saved through the warnings.

Unimportant local floods occurred in the Trinity and Colorado Rivers of Texas. Low initial stages and dry soil militated against destructive rises, and no damage of consequence resulted.

The following report on the floods in Colorado, New Mexico, Utah, and Arizona was prepared by Mr. J. M. Sherier, in charge of the Denver, Colo., forecast district:

REPORT OF FLOODS IN THE DENVER DISTRICT DURING JUNE, 1921.

ARKANSAS RIVER.

During the night of June 2–3, the Arkansas River rose rapidly to a crest stage of 12 feet at Pueblo, or 2 feet above the flood stage, due to heavy rains at and immediately above that city. By the morning of the 3d, the water had receded to 5.6 feet, and no serious damage appears to have been occasioned. Flood stages at points farther down the Arkansas were not reached as a result of this crest.

Information as to the stage referred to was received by mail, on the usual postal card form, no telegraphic report apparently having been made by the Pueblo station at the time.

Late in the afternoon of the 3d and during the night of the 3d–4th, excessive precipitation occurred over that portion of the Arkansas drainage area from Canon City to Pueblo and from Colorado Springs to Pueblo, with torrential local downpours between Penrose and Pueblo, especially in the vicinity of Swallows, about 15 miles west of Pueblo. Well-authenticated records of 6 inches, or more, of precipitation during the 48 hours ending on the afternoon of the 5th have been received from the section referred to, while it is claimed locally that the downpour at Boggs Flat, 10 miles southwest of Pueblo, amounted to 14 inches during the 48 hours after 3 p. m. of the 3d. Although the rainfall here was measured by private individuals in tubs and buckets, the remarkable erosion indicated plainly the exceptional amount of precipitation, a hard-surfaced road leading through the practically level country having been washed out in places to a depth of 7 feet.

The first information in regard to the disastrous flood at Pueblo of June 3–4 which reached the Denver office was contained in the circuit

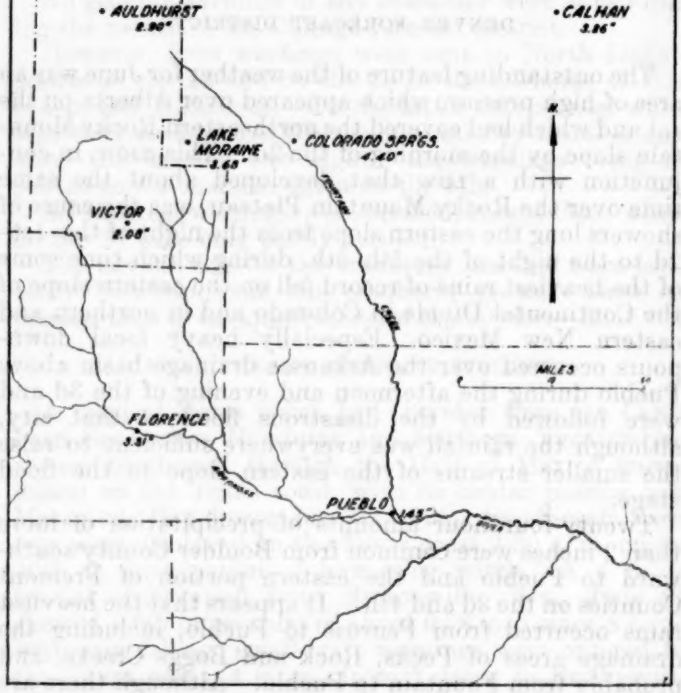


FIG. 1.—Precipitation ending a. m., June 4, 1921, at stations in the vicinity of Pueblo, Colo., Arkansas Basin.

message from that station on the morning of Saturday, the 4th. Besides the regular cipher report, the telegram contained the following statement:

"Continuous rain 11 hours ended five Saturday morning; cloudburst north of city on Friday morning; cloudburst west of city seven Friday night; Arkansas River 12 feet; highest known before levee broke; peak flood water passed Pueblo on Saturday morning; water receding rapidly."

A warning was prepared immediately after 8 a. m. and telegraphed to postmasters from Nepesta to La Junta, inclusive. The same warning was also sent to postmasters from Las Animas to Holly, Colo., except that the time of arrival of the crest was given as "to-night or Sunday morning."

The Weather Bureau offices at Dodge City and Wichita, Kans., were also warned that the highest stages in the Arkansas River in recent years were indicated to the Kansas line within the next 24 hours.

After the disaster at Pueblo, communication with points in southern Colorado and eastern New Mexico was generally greatly delayed and in some cases almost destroyed, especially in the Arkansas Valley. On Sunday afternoon, after one Denver newspaper had issued an extra edition announcing the breaking of Beaver, Skagway and Shafer Dams, north of Florence, Colo., and the information had been confirmed by another local journal, visits were made to the telephone office and railroad offices in attempts to secure direct communication with points

along the Arkansas River east of Pueblo, but without success. The weather map and the occasional reports from special stations indicated that rain had been falling heavily, and the telegram that had been received from Pueblo at 10:30 a. m. stated that the stage at that station at 9 a. m. was 17 feet, but falling. The following additional warning was, therefore, issued at 5:30 p. m. to places from Nepesta to Holly, Colo., and to the officials in charge at Dodge City and Wichita, Kans. "All available information indicates highest known stages Arkansas River during present flood. Every protective precaution necessary." The warning was sent by the Western Union Telegraph Co. via Kansas City, and a service tracer showed that all messages, with the exception of the telegram to the Postmaster, Swink, Colo., had been delivered at 10:40 p. m.

It was afterwards learned that only one of the three dams above Pueblo, Shafer Dam, went out, and that the stage produced at Pueblo was approximately 19 feet at 4 p. m. of the 5th, or 2 feet higher than the stage at 9 a. m. of the same day.

The time of arrival and the height of the flood crests have been reported as follows: Pueblo, between 1 a. m. and 2 a. m. of the 4th, 24.66 feet; 9 a. m., June 5, approximately 17 feet; 4 p. m., June 5, approximately 19 feet. The gage had been destroyed during the night of the 3d–4th, and the height of succeeding crests can not be given exactly. The absolute stage referred to has been determined by the State engineer. Manzinola: 9:30 a. m., 4th, 11.2 feet "above normal surface of river." Fort Lyon: 11 p. m., 4th, 15 feet; 7th, 10.8 feet. Prowers: 3:30 p. m., 5th, "approximately 5 feet high". Lamar: 12 noon, 5th, 13.2 feet; 4 a. m., 7th, 10.7 feet. Holly: About 8 p. m., 5th, "about 18 inches below the main Santa Fe track". The stream fell rapidly after the passage of the last crest and apparently passed below the flood stage at Pueblo during the 8th.

According to the official in charge at Pueblo, the flood stage in the Fountain River was reached late in the night of the 3d–4th, and the crest passed Sunday forenoon. Every bridge across the river was carried away completely, with the exception of the East Fourth Street bridge. The approach and the one adjacent span on the east end of this bridge were washed away, and the remaining portion was badly damaged. The gage on the Fountain was also destroyed.

Estimates of losses in the Arkansas Valley vary greatly, and those made under the direction of Mr. J. S. Savage, United States Reclamation Service, Denver, have been accepted in their entirety. Representatives of the Reclamation Service spent a great deal of time in making a survey of the flooded section, and their reports are thought to be more reliable than any others that could be obtained without great expense. Mr. Savage found the losses to have been approximately as follows: Bridges, roads, buildings, etc., $17,403,000; farm property and crops, $3,238,000; live stock and other movable property, $438,000; suspension of business, several millions. Value of property saved through warnings impossible to estimate with any degree of accuracy.

CANADIAN RIVER.

Owing to a report of 1.70 inches of rainfall in eight hours at Tucumcari, N. Mex., and to the conditions shown on the morning map, a warning of rapidly-rising stages at Logan, N. Mex., during the next two days was issued at 10 a. m. of the 4th. At 11 a. m. of the 5th, after continued heavy rains, warning of an 18-foot stage, or higher, was issued for the same station. The highest stage reported from Logan was 15 feet at 5 p. m. of the 5th, at which time the stream was still rising. At 2 p. m. of the 6th the stage had fallen to 9 feet.

No damage has been reported.

PECOS RIVER.

On account of heavy rains in the upper portion of the drainage area, a warning of rapidly rising stages at Roswell, N. Mex., was issued at 11 a. m. of the 4th. Because of continued heavy rains, warning that the flood stage would be exceeded within the next 24 hours was issued at 11 a. m. of the 5th for Santa Rosa and Fort Sumner, N. Mex., and warning of a further decided rise in the Pecos during the next 36 hours was issued for Roswell. Warnings that rising stages at Carlsbad, N. Mex., were indicated for several days, exceeding the flood stage in the next 24 hours; and that rising stages at Barstow, Tex., were indicated for several days, exceeding the flood stage within the next 48 hours, were also issued at the same time. The highest stage at Santa Rosa during the flood was 11.3 feet, at 8 a. m. of the 4th; at Highway Bridge, 12 feet, at 10 p. m. of the 5th, and at Pecos, Tex., 11.8 feet, at 8 a. m. of the 10th. A stage of 11 feet was reached at the last-named place at 8 a. m. of the 7th. A stage of 12 feet occurred at Barstow, Tex., on the 19th, due to local showers, for which no warning had been issued. Warning of a considerable rise in the lower Rio Grande was issued at 10 a. m. of the 19th, after receipt of the telegram containing the flood stage for Barstow already referred to. Actual loss reported of bridges, roads, levees, etc., amounted to $24,000; of crops, etc., $20,000. No other losses occurred. Money value of property saved by warnings not known.

RIO GRANDE.

At 8:30 p. m. of the 4th, warning of rising stages in the upper Rio Grande as far southward as San Marcial were issued because of the heavy rains that had occurred over the upper portion of the drainage area.

At 11:30 a. m. of the 5th, after further heavy rains in the upper drainage area, warning of flood stages was issued for places above San Marcial during the next 24 to 36 hours, and a stage of about 15 feet was predicted for San Marcial within the next two or three days. The rainfall in northern New Mexico became lighter, however, and the highest stage reported from Espanola, N. Mex., was 5.4 feet on the 8th, and from Albuquerque, N. Mex., 3 feet, on the 5th. No report has been made by the river observer at San Marcial.

Because of the rapid melting of the snow at the highest elevations and the rising stages in the extreme upper portion of the drainage area, warning was issued at 11 a. m. of the 14th that rising stages in the Rio Grande were indicated for several days, approaching the flood stage at Albuquerque and probably exceeding 15 feet at San Marcial. The highest stage reached at Espanola was 6 feet on the 16th and 17th; at Albuquerque, 3.8 feet, or 0.2 foot below the flood stage, on the 18th. No report was received from San Marcial.

Excepting the washing away of a bridge at Embudo and of another at Chamita and of 120 feet of the west end of the bridge at Espanola, when the stage of the last named place was between 5.7 feet and 6 feet, the money equivalent of which losses was not given, no special damage has been reported from the upper Rio Grande.

SAN JUAN RIVER.

Warning of a rapid rise in the San Juan in the next 48 hours, considerably exceeding the flood stage, was issued for Farmington, N. Mex., on the 14th. The highest stage at that place was 8.2 feet, or 0.2 foot above the flood stage, on the 16th.

No damage resulted.

GUNNISON RIVER.

Flood stages in the Gunnison prevailed at the beginning of the month. On the 7th, because of a further rise at Paonia and Sapinero, Colo., warning was issued of an expected stage of about 10 feet at Delta, Colo., within the next 24 to 36 hours. The highest reading at that place was 9.5 feet at 12:30 p. m. of the same day.

On the 10th, because of warm weather and the melting of snow at the higher elevations, warning of a further rise was issued for the lower Gunnison, with stages near or above the flood stage. The highest stages along this stream were as follows: Paonia, 9 feet, on the 7th; Sapinero, 21.2 feet, on the 12th and 13th; Delta, 10 feet, on the 12th and 15th. The river was below the flood stage at Sapinero after the 24th; at Paonia after the 18th, and at Delta after the 17th.

No flood losses of consequence occurred.

GRAND RIVER.

At the beginning of the month, the Grand River was about, or somewhat above, the flood stage, with no important changes during the first seven or eight days. Owing to rising stages in the Gunnison, warning was issued on the 7th of a stage of about 11.5 feet at Grand Junction within the next 24 hours, and of a stage at Fruita slightly above 14 feet. At Grand Junction the reading was 11.1 feet at 7 p. m. of the 7th, and at Fruita the stage on the morning of the 8th was 13.6 feet.

Because of the rapid melting of snow at the higher elevations, warnings of a further rise, with stages near, or above the flood stage, was issued for the lower Grand on the 10th. At 8 p. m. of the 14th, warning of a further decided rise in the lower Grand was issued because of excessive rains at Rogers Mesa. On the morning of the 15th, warning was issued of the following expected stages: Grand Junction, about 13 feet, next 36 to 48 hours; Fruita, slightly above 15 feet, next 48 hours. The reading at Grand Junction was 12.5 feet at 11 a. m. of the 16th, the observer at that station also reporting that the stage in the north channel of the river was 13 feet. At 8 a. m. of the 16th the stage at Fruita was 15.2 feet.

The river passed below the flood stage at Eagle on the 18th; at Grand Junction by the morning of the 18th; and at Fruita by the morning of the 20th.

Losses to bridges, roads, etc., $3,100; to crops, $5,350; value of property saved by warnings, about $1,200.

GREEN RIVER.

The lower Green River was also in flood at the beginning of the month, the stage at Elgin, Utah, ranging from 13 feet on the 1st to 13.6 feet on the 8th. On account of warm weather a warning that continued high and slightly rising stages were probable at Elgin for several days was issued on the morning of the 10th, when the stage had reached

15 feet. Because of steadily rising stages in the upper Green, a warning was issued on the morning of the 15th that a stage of 17 feet was indicated at Elgin by the morning of the 18th. Much cooler weather, however, checked the melting of snow at the higher elevations and the river remained at 16.3 feet from the 15th to the 17th, after which latter date it began to fall, passing below the flood stage of 13 feet on the 23d.

Losses, bridges, roads, etc., $3,600; to crops, $10,000; value of property saved through warnings, $250,000.

In explanation of the latter item Mr. H. T. Howland, the river observer at Elgin, states that the advices issued enabled those engaged in the protection of a dam at that place to keep ahead of the rise in the stream.

COLORADO RIVER.

Rising stages prevailed in the lower Colorado at the beginning of the month, when the river had just reached the flood stage of 14 feet at Topock, and the reading at Yuma was 24.2 feet. The following table shows a comparison of observed and predicted stages and discharges:

Observed and predicted stages and discharges of the Colorado River.

Date.	Place.	Predicted—		Observed—	
		Stage.	Discharge.	Stage.	Discharge.
		Feet.	*Second-feet.*	*Feet.*	*Second-feet.*
June 14	Topock, Ariz.	21		19.5	
17	do	22.5		22.0	
20	Yuma, Ariz.	28.5	130,000	27.5	124,000
22	Topock, Ariz.	26.0		26.8	
23	Yuma, Ariz.	29.5	140,000	29.2	148,000
28	do	31.0	170,000	31.3	185,700

The following additional warning was issued for Yuma: "Crest stage about 31 feet, discharge about 170,000 second-feet indicated by June 28." The final stage at Parker was 12.4 feet, on the 22d, and at Yuma 31.3 feet on the 28th, with a discharge at the latter place of 185,700 second-feet.

Losses to buildings, roads, etc., $75,000; to crops, probably not great, data not available; to prospective crops, $155,250.

Of the prospective crop losses reported, $100,000 was due to seepage and $55,250 to the breaking of a levee on July 2, after the river had fallen to a stage of 23.2 feet, or nearly 2 feet below the flood stage, and all danger was thought to be over. An interesting account of this occurrence which has been received from the official in charge at Yuma, is inclosed, together with a photograph of the Southern Pacific Railroad bridge, taken when the flood was about at its crest. (Photograph not reproduced.)

It seems almost impossible to obtain reliable estimates as to the money value of property saved by warnings. In this connection, the official in charge at Yuma reports, "Doubtless the warnings have an enormous value in giving gage heights to be expected but the flood, being an annual affair, is always watched for." In a letter dated June 23 the same official, in a discussion of the condition of the levee system of the Imperial irrigation district, in which there are nearly 1,000,000 acres of land, stated that rock trains were rushing work on both sides of the river to prevent a threatened break which would result in the flooding of the Imperial Valley. The firm of Allison & Entenmann, Calexico, Calif., reports, "Forecasts by Department probably saved major part of Imperial Valley from flood damage. Work is of inestimable value." In view of the fact that the extreme stage of the present year was the highest of record for any summer month, and after a consideration of the other information on hand relative to this matter, it is thought that the foregoing statement, while it may appear to be strong, is justified.

The following excerpts from a letter from Mr. A. S. Peck, District Forester, Denver, Colo., also contains some valuable information and data bearing upon the Pueblo flood:

At the intake of the Colorado Springs water supply on Ruxton Creek, 3 miles west of Manitou, the total precipitation for the period of June 3-7 (6 p. m.) is 6.33 inches. This record was taken by Mr. Clyde McReynolds, outside superintendent of the Colorado Springs Water Commission, twice during the storm and the figures are thought to be fairly reliable.

At Minnehaha, on the same creek, but 1 mile to the east, measurements were secured from one of the instructors in charge of a summer school for graduate students and teachers. This record is considered accurate as the students are accustomed to gathering and recording scientific data. Measurements were taken at 10:30 a. m. and the record follows:

The rain started at 3 p. m., June 3, and after 4 p. m. was heavy throughout the night.

June 4	4.64
June 5	2.56
June 6	.20
June 7	.45
June 8 and 9	.64
Total	8.49

At the Skagway Reservoir, 7 miles east of Victor, 7.5 inches of water were measured on the morning of June 5 in a bucket which stood on the breast of the reservoir during the storm.

Dr. F. E. Knoch, superintendent of the United Oils Co., at Florence, is responsible for the following measurements, which are considered very reliable, as he has been making measurements of precipitation, temperature, and barometric pressure for some time for use of his company. Measurements are taken at 8 a. m.

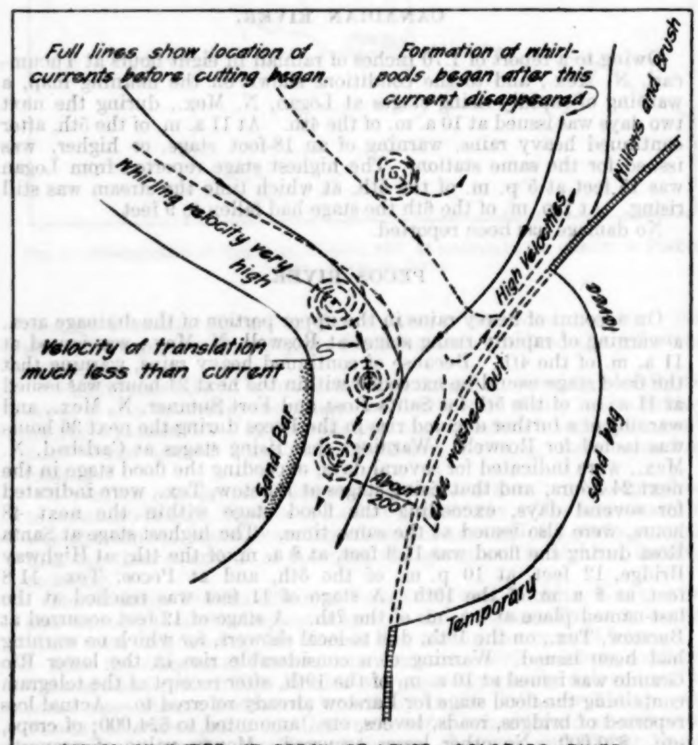
June 3 (rain during night)	0.99
June 4 (started 3 p. m., June 3)	3.31
June 5	2.47
June 6	.13
Total	6.90

Mr. J. C. Magruder, superintendent of the Beaver Valley Land Co., at Penrose, stated that he measured 10 inches of rain from 3 o'clock June 3 to June 7. The water in the gage ran over and this figure was secured from the gage measurements and an estimate of that which ran over. It is checked by a measurement of 10.5 inches made, in a rain gage, for the same period, in Beaver Park, 3 miles south of Penrose, by L. F. Johnson. The latter figure is supposed to be fairly reliable.

From all local accounts, and the evidence on the ground, it is believed that the heaviest rainfall occurred from Penrose to Pueblo, including the drainage of Pecks, Rock, and Boggs Creeks that flow into the Arkansas from the south, and probably the region from Fountain to Pueblo. Unfortunately there are few reliable figures for this region, and it seems hard to credit a rainfall of 14 inches, such as was reported on Boggs Flat, 10 miles southwest of Pueblo. The deep erosion and large volume of water carried by all drainage courses indicate that the rainfall was very heavy there.

The following is a portion of a special report by Mr. James H. Gordon, official in charge of the Weather Bureau Office at Yuma, Ariz.:

The inclosed blue print [see fig. 2] and a portion of the report of Manager T. J. Preston of the Yuma project to the chief engineer of the



ACTION OF WATER AT BREAK OF LEVEE, COLORADO RIVER, YUMA PROJECT, ARIZONA-CALIFORNIA JULY 1, 1921

FIG. 2.

Reclamation Service may be of interest. These serve to illustrate and describe the unique phenomenon of a river damming itself with its own water:

"On June 29 and 30 it was observed that the river rose and fell above the point where the river was contracted. A gage a short distance above was observed to have a fluctuation of 1.8 feet. A series of whirlpools formed on the inside of the curve above the contracted section, which had a clockwise movement. These apparently had a radius of from 50 to 75 feet. Their movement downstream was slow. It was observed that as they passed through the contracted section of the channel they had the effect of choking it and it was at these periods that the water rose on the gage above mentioned 1.8 feet above its level at other times. No measurements, of course, could be made of the depression of the water in these whirlpools, but it was estimated to be about 3 feet. From the levee to the center of the whirlpool was in many cases not over 200 feet. As the flow of the water was upstream on the opposite side of these whirlpools, the whole river was compelled to pass through a much more contracted section when the whirlpool was slowly passing than it was at other periods. As these whirlpools passed through the contracted section the water piled up on the upper side, breaking against the levee, causing currents along the levee to flow both upstream and downstream with tremendous velocities. It was impossible to ascertain the velocities of these currents. The velocities upstream far exceeded the velocities at Yuma, which were around 7 feet per second during the flood. This also set up secondary whirlpools which had a counter-clockwise movement that moved upstream. [See figure 2.] The frequency of the passage of these whirlpools varied from 4 to 6 minutes."

Every available agency was used by the Reclamation Service to hold the levee at this point, but without success. Thirteen hundred feet of levee went into the river, carrying about 900 feet of railroad track with it. About the same length of the west main canal was washed out, and an estimated stream of 2,000 second-feet poured through onto some of the richest land in the Yuma Valley. By the use of lateral canals as bases for levees, the water was kept within an area of slightly over 1,700 acres. As the river dropped a sandbag levee was built to temporarily replace the washed-out section and attention was turned to draining the flooded land and replacing the washed-out canals. The loss from flooding is placed at $55,000, while the damage to levee and canals amounted to about $75,000.

The crest of the Arkansas River flood crossed the Colorado-Kansas line during June 5, augmented by some heavy Kansas rains, and reaching Dodge City at midnight June 7, Great Bend about noon June 10, Hutchinson June 13, and Wichita about 7 p. m., June 16. No flood stages were reported east of Wichita. Details of stages were as follows:

Stations.	Flood stage.	Crest. Stage.	Crest. Date.	Above flood stage.	Above previously recorded highest water.
	Feet.	Feet.		Feet.	Feet.
Dodge City, Kans	5	7.0	Midnight, June 7	2.0	0.3
Great Bend, Kans	5	[1] 7.7	About noon, June 10	2.7	1.9
Hutchinson, Kans	6	[1] 7.9	June 13	1.9	2.3
Wichita, Kans	9	9.3	About 7 p. m., June 16	0.3	[2] 1.7

[1] Estimated. [2] Below.

About 57,785 acres of Kansas farm lands were overflowed and the cities of Dodge City, Great Bend, and Hutchinson were overflowed. Losses and damage were as follows:

Buildings, bridges, etc	$186,190
Crops and farm property	61,500
Crops, prospective	718,741
Live stock, etc	10,000
Suspension of business	25,000
	1,001,431

Value of property saved through warnings, $149,000.

On June 14, the Arkansas River broke over its right bank near Maize, Kans., about 12 miles northwest of Wichita, cutting a new channel. The overflow water was thereby diverted into the Big Slough, a tributary flowing parallel to the Arkansas River and emptying into it about 5½ miles below Wichita. Extensive farming areas along the Big Slough were overflowed, and they were not freed from flood waters until June 30.

There was another moderate overflow at Great Bend during the night of June 18–19, but without damage, and also a decided rise in the Little Arkansas River on June 22, the latter due to heavy rains over the immediate drainage area. Flood warnings were issued at 10 a. m., June 22, and no damage was done, as the flood stage was not exceeded at any place.

Floods during the month of June, 1921.

River and station.	Flood stage.	Above flood stages—dates. From—	Above flood stages—dates. To—	Crest. Stage	Crest. Date.
MI I IPPI DRAINAGE.					
Missouri:	Feet.			Feet.	
St. Charles, Mo	25	29	(**)	26.4	30
Blair, Nebr	16	28	30	16.2	29
Grand:					
Brunswick, Mo	10	29	(**)	12.2	30
Yazoo:					
Yazoo City, Miss	25	(*)	1	25.5	1
North Canadian:					
Woodward, Okla	3	1	2	4.8	1
Do	3	6	12	5.8	9
Do	3	21	28	5.0	21
Do	3	30	(**)	3.6	30
Oklahoma City, Okla	12	14	14	12.1	14
Arkansas:					
Pueblo, Colo	10	2	8	24.7	4
Do	10	14	14	14.0	14
Fort Lyon, Colo	6	4	8	15.0	4
Dodge City, Kans	5	6	10	7.0	8
Great Bend, Kans	5	10	12	6.3	12
Wichita, Kans	9	16	18	9.3	17
Little Arkansas:					
Sedgwick, Kans	18	22	22	18.7	22
Sulphur:					
Finley, Tex	24	28	(**)	28.6	30
Ringo Crossing, Tex	20	12	12	20.0	12
Do	20	23	(**)	30.0	27
Neosho:					
Fort Gibson, Okla	22	27	27	22.0	27
COLORADO DRAINAGE.					
Colorado:					
Topock, Ariz	14	(*)	26	26.8	22
Parker, Ariz	7	(*)	(**)	12.4	22
Yuma, Ariz	25	6	(**)	31.3	28
Grand:					
Grand Junction, Colo	11	10	17	12.5	16
Fruita, Colo	12	(*)	19	15.2	16
Eagle:					
Eagle, Colo	5	10	17	6.0	15
Gunnison:					
Sapinero, Colo	16	(*)	24	21.2	12-13
Delta, Colo	9	(*)	1	9.0	1
Do	9	5	17	10.5	15
North Fork—Paonia, Colo	8	(*)	18	9.0	7, 15
Green:					
Elgin, Utah	13	1	22	16.3	15
San Juan:					
Farmington, N. Mex	8	15	16	8.2	16
PACIFIC DRAINAGE.					
Kings:					
Piedra, Calif	12	7	12	12.7	8, 10, 11
Columbia:					
Marcus, Wash	24	(*)	(**)	32.1	13
Wenatchee, Wash	40	3	21	44.4	11-12
The Dalles, Oreg	40	7	16	42.4	11
Vancouver, Wash	15	(*)	(**)	25.2	12
Kootenai:					
Bonners Ferry, Idaho	26	7	15	27.9	10
Pend Oreille:					
Newport, Wash	16	(*)	26	19.8	13
Willamette:					
Portland, Oreg	15	(*)	(**)	24.3	12-13

*Continued from May. ** Continued into July.

MEAN LAKE LEVELS DURING JUNE, 1921.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., July 5, 1921.]

The following data are reported in the "Notice to Mariners" of the above date.

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during June, 1921:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.43	580.58	573.02	246.61
Above or below—				
Mean stage of May, 1921	+0.31	0.00	−0.07	−0.07
Mean stage of June, 1920	−0.21	−0.27	+0.54	+1.05
Average stage for June, last 10 years	+0.10	−0.31	+0.13	−0.23
Highest recorded June stage	−1.00	−3.02	−1.50	−2.02
Lowest recorded June stage	+1.19	+0.68	+1.45	+1.72
Average relation of the June level to:				
May level		+0.30	+0.20	+0.20
July level		−0.10	0.00	0.00

* Lake St. Clair's level in June, 575.69 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JUNE, 1921.

By J. B. KINCER, Acting Chief of Division.

[Weather Bureau, Washington, July 25, 1921.]

The weather during June was generally favorable for outdoor work in practically all sections of the country, except for considerable interruption to harvest and cultivation of row-crops from the southern Great Plains southward to the Gulf. In other sections cultivation made rapid progress and fields were generally clean at the close of the month. Temperatures were high for the season in the central and northern sections of the country and favorable for warm-weather crops wherever moisture was sufficient. Rainfall was generally ample west of the Mississippi River, but was deficient in many sections to the eastward, particularly in localities from the Ohio Valley southward.

The weather was generally favorable for corn, especially in the trans-Mississippi States, and that crop made satisfactory advance throughout the principal producing area, except that it was in need of moisture in some east-central and southeastern districts, particularly in the latter area. The high temperatures caused wheat to ripen rapidly in Central and Northern States, in fact too rapidly in many localities, and considerable harm resulted. Spring wheat was favorably affected by the weather during the first half of the month, but the latter half was less favorable for this crop; it was too warm for best development and droughty conditions prevailed in some sections. It was also too warm for oats and potatoes in central and northern districts and too dry in many eastern localities, although there was improvement by rains the latter part of the month in some east-central districts.

Cotton made fairly good advance in most sections of the belt during the month, with steady improvement reported quite generally. The latter part of the month received too much rain, however, in Texas, Oklahoma, and Arkansas, while the soil had become very dry in some Eastern States, particularly in Georgia. Cultivation was hindered in the northwestern portion of the belt and the fields became grassy. Weevil activity increased materially during the month; they were numerous in the southeastern portion of the belt and doing considerable damage notwithstanding the dry weather.

Meadows and pastures made satisfactory growth between the Mississippi River and the Rocky Mountains, as a rule, and ranges continued in good condition in the upper and most central Rocky Mountain States, but were very dry and stock suffered for lack of water in the far Southwest. Grass and truck crops suffered for moisture also in many localities east of the Mississippi River.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, June, 1921.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	° F.	° F.		° F.			° F		In.	In.		In.		In.
Alabama	81.0	+2.9	Maple Grove	103	27	St. Bernard	56	3	1.89	−2.18	Scottsboro	4.27	Troy	0.20
Arizona	76.0	+0.1	Mohawk	119	11†	3 stations	27	1†	0.27	0.00	Pinto	1.46	18 stations	0.00
Arkansas	78.5	+2.1	2 stations	103	3†	Hardy	46	8	4.84	+0.60	Grannis	12.03	Osceola	1.41
California	68.7	−0.3	Greenland Ranch	120	10†	2 stations	28	1	0.16	−0.15	Madeline	2.30	79 stations	0.00
Colorado	61.5	+0.5	Burlington	101	27	....do	20	1†	3.00	+1.52	Silver Lake	12.36	Cascade	0.35
Florida	80.5	+0.7	4 stations	102	16†	Glen St. Mary	55	9	3.52	−2.74	Lynne (near)	8.85	Garniers (near)	0.15
Georgia	80.2	+2.0	5 stations	104	14†	Blue Ridge	52	1†	2.63	−2.00	Waycross	7.59	Griffin	0.28
Hawaii (May)	72.6	+0.8	Mahukona	94	28	Waimea	48	4	2.66	−3.35	Eke	14.50	Haleakala Ranch	0.00
Idaho	62.9	+2.8	Glenns Ferry	106	19	Bostetter R. S.	25	17	0.89	−0.40	Oxford R. S.	2.42	2 stations	T.
Illinois	76.6	+5.2	2 stations	100	18†	Freeport	37	5	3.75	−0.08	Windsor	7.47	Urbana	1.68
Indiana	76.1	+4.7	Hobart	102	17	Hobart	37	5	3.51	−0.33	Butlerville	7.17	Paoli	1.02
Iowa	74.7	+5.6	2 stations	100	28†	Fayette	40	5	3.76	−0.62	Knoxville	8.85	Alton	0.56
Kansas	74.4*	+1.6	....do	101	27†	Wallace	44	3	5.10	+0.81	Osage City	12.56	Republic	1.08
Kentucky	77.8	+4.1	Mayfield	100	30	2 stations	46	5†	2.92	−1.26	Falmouth	5.35	Earlington	0.78
Louisiana	80.3	+0.2	Plain Dealing	101	1	Calhoun	59	3	5.42	+0.55	Houma	9.58	Burrwood	0.53
Maryland-Delaware	72.4	+2.2	Cambridge, Md	102	28	Grantsville, Md	34	6	2.50	−1.54	Grantsville, Md	6.49	Ferry Landing, Md	0.10
Michigan	68.5	+6.1	2 stations	100	17†	Houghton	23	5	2.21	−0.92	Muskegon	8.18	Frankfort	0.05
Minnesota	70.3	+6.2	Fergus Falls	105	30	Roseau	28	4	2.90	−1.27	Fosston	8.12	Chatfield	0.60
Mississippi	80.5	+1.9	Okolona	103	19	Duck Hill	59	3	2.94	−1.43	University	6.26	Grenada	0.73
Missouri	76.6	+3.4	Caruthersville	105	1†	2 stations	44	5†	5.71	+1.15	Warsaw	11.39	St. Louis, No. 1	2.31
Montana	63.2	+3.6	Broadus	104	11	Babb	23	12	2.50	+0.01	Springbrook	16.79	Virginia City	0.77
Nebraska	73.0	+3.8	Grand Island	104	28	Harrison	41	20	2.35	−1.44	Crete	6.12	Genoa	0.51
Nevada	67.7	+2.2	Logandale	115	30	Marlette Lake	20	18	0.40	−0.05	Golconda	1.45	8 stations	0.00
New England	64.1	0.0	Lawrence, Mass	97	20	Van Buren, Me	27	6	2.73	−0.53	Torrington, Conn	5.07	Westboro, Mass	0.41
New Jersey	70.4	+1.8	Paterson	100	22	Charlotteburg	33	2†	3.23	−0.30	Plainfield	5.64	Northfield	1.40
New Mexico	66.4	−1.8	Elephant Butte	107	26	Red River Canyon	21	19	3.55	+1.95	Pasamonte	10.24	Deming (near)	0.02
New York	66.4	+1.6	Farmingdale	99	24	Indian Lake	26	5	2.76	−0.83	Mount Hope	5.73	Brockport	0.55
North Carolina	75.1	+1.8	Nashville	103	27	Wenona	39	7	3.04	−2.08	Marion	6.38	Louisburg	0.41
North Dakota	68.3	+5.5	2 stations	108	30	Hansboro	30	3	3.55	+0.55	Powers Lake	7.65	Linton	0.75
Ohio	73.4	+4.2	....do	99	13	3 stations	37	5	2.81	−0.93	Beverly	6.21	Danbury	0.92
Oklahoma	76.2	−0.6	Beaver	101	30	Kenton	48	19	8.12	+4.24	Tulsa	13.57	Goodwell	2.33
Oregon	62.1	+2.2	2 stations	100	6†	Blitzen	20	15†	1.29	−0.08	Astoria	5.08	Ortley	0.02
Pennsylvania	70.6	+2.7	Catawissa	101	27	West Bingham	26	5	3.12	−1.18	Coroapolis	9.86	Carlisle	0.70
Porto Rico														
South Carolina	79.2	+1.7	6 stations	103	14	3 stations	50	5†	2.81	−2.08	Ferguson	5.71	Chappells	0.33
South Dakota	72.5	+6.9	3 stations	107	29†	Pollock	36	3	2.01	−1.59	Deerfield	8.35	Redfield	0.19
Tennessee	78.1	+3.8	....do	100	2†	Mountain City	44	6	2.86	−1.66	Moscow	7.38	Celina	0.44
Texas	79.4	−0.8	Encinal	108	24	Clint	45	19	6.58	+3.39	Austwell	22.06	George West	0.57
Utah	66.0	+2.1	St. George	108	11	3 stations	25	1†	0.38	−0.22	Watson	2.51	15 stations	0.00
Virginia	73.0	+1.5	2 stations	102	14†	Onley	40	6	2.50	−2.03	Leeds Manor	5.60	New Canton	0.88
Washington	62.0	+1.9	Hanford	103	23	Paradise Inn	27	3	1.65	+0.09	Paradise Inn	12.30	Wahluke	T.
West Virginia	72.4	+3.2	Huntington	101	25	3 stations	38	6	4.01	−0.44	Smithfield	8.67	Wardensville	0.47
Wisconsin	70.1	+5.6	2 stations	102	30	5 stations	27	4	2.30	−1.52	Mondovi	7.50	Burnett	0.52
Wyoming	61.6	+3.3	Fort Laramie	104	30	FoxPark	22	1	2.15	+0.36	Dwyer	5.83	Lovell	0.06

*For description of tables and charts, see REVIEW, January, 1921, p. 41.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, June, 1921.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
New England.							64.2	+ 0.7										72	2.71	− 0.4										5.2		
Eastport	76	67	85	29.81	29.89	− .04	55.6	+ 1.2	77	24	64	44	5	48	27	51	48	81	1.02	− 2.2	13	5,724	s.	29	nw.	1	4	13	13	6.7	0.0	0.0
Greenville, Me	1,070	6		28.76	29.90		60.0		86	23	71	34	5	49	36				2.88		15						9	10	11		0.0	0.0
Portland, Me	103	82	117	29.81	29.93	− .02	63.3	+ 0.7	90	23	72	45	5	55	28	56	51	65	2.70	− 0.7	10	6,542	nw.	31	nw.	12	13	8	9	4.9	0.0	0.0
Concord	288	70	79	29.63	29.93	− .03	64.8	+ 0.4	94	22	78	39	5	52	40				4.16	+ 0.8	7	3,381	w.	24	nw.	14	16	11	3	4.0	0.0	0.0
Burlington	404	11	48	29.52	29.94	− .02	64.2	+ 0.4	92	22	75	37	5	53	35				1.96	− 1.3	9	6,348	s.	34	s.	13	8	13	9	5.4	0.0	0.0
Northfield	876	12	60		29.95		60.2	− 2.5	89	22	75	31	5	46	43			70	2.56	− 0.7	11	4,868	s.	29	nw.	13	5	18	7	5.5	0.0	0.0
Boston	125	115	188	29.80	29.93	− .03	68.2	+ 2.4	93	22	77	49	5	59	27	61	55	65	3.58	+ 0.6	6	7,079	sw.	30	n.	15	12	12	6	4.9	0.0	0.0
Nantucket	12	14	90	29.93	29.94	− .04	62.7	+ 1.4	84	24	69	47	3	56	22	59	57	84	2.79	+ 0.4	10	10,506	sw.	37	sw.	21	12	5	13	5.6	0.0	0.0
Block Island	26	11	46	29.92	29.96	− .01	63.0	+ 1.4	80	24	69	50	3	57	18	59	58	87	2.56	− 0.3	7	10,435	sw.	45	n.	18	9	12	9	5.6	0.0	0.0
Providence	160	215	251	29.77	29.94	− .03	67.8	− 0.5	93	22	78	48	5	58	27	60	54	64	3.35	+ 0.2	9	8,383	sw.	44	n.	15	11	14	5	4.7	0.0	0.0
Hartford	159	122	140	29.78	29.95	− .02	68.2	+ 1.1	95	22	79	47	2	58	33	59	53	62	1.63	− 1.4	10	5,403	sw.	31	sw.	13	11	12	7	4.9	0.0	0.0
New Haven	106	74	153	29.85	29.96	− .01	68.2	+ 1.3	90	22	78	49	2	58	29	61	56	69	3.46	+ 0.3	11	6,205	sw.	31	n.	14	13	11	6	4.5	0.0	0.0
Middle Atlantic States.							71.6	+ 1.4										67	2.16	− 1.5										4.6		
Albany	97	102	115	29.84	29.95	− .02	68.4	+ 0.5	94	22	80	44	2	57	34	60	54	62	2.69	− 1.1	9	5,116	s.	28	nw.	15	21	4	5	3.2	0.0	0.0
Binghamton	871	10	84	29.07	29.98	+ .01	67.6	+ 1.4	92	27	80	39	5	55	36				1.50	− 2.1	7	3,481	nw.	23	nw.	15	10	14	6	5.0	0.0	0.0
New York	314	414	454	29.64	29.96	− .02	70.3	+ 1.8	93	22	79	53	3	62	28	61	56	64	3.25	0.0	8	10,911	sw.	63	w.	11	8	14	8	5.4	0.0	0.0
Harrisburg	374	94	104	29.50	29.98	− .01	72.8	+ 2.5	95	28	83	50	5	63	29	62	56	58	1.74	− 1.8	7	2,748	s.	24	nw.	28	10	12	8	5.0	0.0	0.0
Philadelphia	117	123	190	29.87	29.99	+ .01	73.4	+ 2.2	95	24	83	54	3	64	26	66	62	72	2.86	− 0.4	7	6,900	sw.	31	s.	29	11	8	11	5.1	0.0	0.0
Reading	325	81	98	29.64	29.98		72.8		96	22	64	51	5	62	35	63	56	59	1.06	− 2.6	7	1,864	se.	25	e.	26	19	6	5	3.7	0.0	0.0
Scranton	805	111	119	29.14	29.98	+ .00	69.4	+ 2.2	94	27	81	45	5	58	35	60	54	60	1.61	− 2.0	9	4,547	sw.	27	sw.	11	11	12	7	5.0	0.0	0.0
Atlantic City	52	37	48	29.92	29.97	− .01	67.7	+ 0.9	94	24	74	51	6	61	25	62	58	73	1.48	− 1.6	8	5,270	sw.	23	ne.	5	17	6	7	3.9	0.0	0.0
Cape May	18	13	49	30.00	30.02	+ .04	69.2	+ 1.5	92	24	77	51	6	62	26	63	60	77	2.50	− 0.5	9	5,454	s.	24	nw.	14	13	11	6	4.6	0.0	0.0
Sandy Hook	22	10	55	29.95	29.97		69.0		91	22	76	52	3	62	23	62	59	73	2.66		7	9,384	sw.	51	nw.	28	12	12	6	4.8	0.0	0.0
Trenton	190	159	183	29.76	29.96		71.1		94	22	82	49	3	60	30	63	58	67	4.83	+ 1.3	8	7,272	sw.	58	n.	27	10	12	8	4.9	0.0	0.0
Baltimore	123	100	113	29.85	29.98	− .01	75.0	+ 2.0	96	28	84	54	5	66	28	65	59	59	1.97	− 1.9	7	4,283	s.	24	sw.	13	12	11	7	4.5	0.0	0.0
Washington	112	62	85	29.86	29.98	− .02	74.2	+ 1.5	96	28	85	50	6	63	32	65	60	65	3.45	− 0.7	7	3,911	sw.	25	nw.	26	13	13	4	4.5	0.0	0.0
Lynchburg	681	153	188	29.27	30.00	− .01	74.3	+ 0.8	95	24	85	50	6	64	32	66	63	71	1.85	− 2.0	8	3,980	e.	27	ne.	30	12	13	5	4.6	0.0	0.0
Norfolk	91	170	205	29.90	30.00	.00	74.8	+ 0.4	94	24	84	55	7	66	27	67	63	71	1.05	− 3.3	7	7,585	ne.	32	ne.	5	10	12	8	5.1	0.0	0.0
Richmond	144	11	52	29.84	29.99	− .02	74.8	− 0.3	98	28	86	52	3	63	31	66	62	69	1.49	− 2.0	8	4,419	sw.	40	w.	23	8	13	9	5.5	0.0	0.0
Wytheville	2,304	49	56	27.70	30.00	− .01	70.3	+ 1.6	87	14	80	50	6	60	33	64	61	77	1.26	− 2.8	9	3,568	w.	19	w.	23	14	13	3	3.7	0.0	0.0
South Atlantic States.							77.7	+ 1.6										73	2.93	− 2.0										5.0		
Asheville	2,255	70	84	27.74	30.02	+ .01	71.8	+ 3.1	87	14	81	54	2	62	27	65	62	79	4.74	+ 0.4	12	4,311	nw.	42	e.	4	4	21	5	5.5	0.0	0.0
Charlotte	779	55	62	29.18	30.00	− .01	78.0	+ 2.5	99	14	89	56	6	67	29	68	64	67	1.33	− 3.1	9	3,000	ne.	19	nw.	25	6	19	5	5.4	0.0	0.0
Hatteras	11	12	50	29.98	29.99	− .02	73.8	− 0.6	90	13	79	58	6	68	18	70	68	83	3.56	− 0.8	10	8,800	sw.	40	ne.	5	5	17	8	5.7	0.0	0.0
Manteo	12	5	42				72.2		91	24	81	49	7	63					2.26		4		sw.				20	5	5		0.0	0.0
Raleigh	376	103	110	29.60	29.90	− .02	76.1	+ 1.0	97	24	86	52	6	66	30	68	63	68	1.14	− 3.6	9	5,096	sw.	27	s.	29	7	16	7	5.4	0.0	0.0
Wilmington	78	81	91	29.92	30.00	− .01	76.6	+ 1.1	96	14	85	51	6	68	25	70	67	77	2.92	− 2.7	9	5,496	sw.	28	ne.	2	5	20	5	5.0	0.0	0.0
Charleston	48	11	92	29.95	30.00	− .01	80.0	+ 1.5	100	17	87	61	6	73	27	72	69	74	0.61	− 4.8	7	7,719	s.	37	w.	29	14	12	4	4.5	0.0	0.0
Columbia, S. C.	351	41	57	29.63	30.00	− .01	79.8	+ 1.6	100	14	91	58	7	69	27	69	65	69	2.53	− 1.6	7	4,320	ne.	31	ne.	19	10	15	5	4.8	0.0	0.0
Due West, S. C.	711	10	55	29.28	30.03		78.6		99	14	90	59	6	67	29				1.65		8	5,198	sw.	34	sw.	24	6	18	6	5.5	0.0	0.0
Greenville, S. C	1,039	113	122	28.92	29.99		77.4		96	14	87	59	6	68	25	68	65	71	1.75		10	4,974	ne.	37	nw.	18	5	24	1	5.2	0.0	0.0
Augusta	180	62	77	29.80	29.99	− .02	81.1	+ 3.0	101	14	92	60	7	70	27	71	66	66	4.56	0.0	9	3,745	s.	36	se.	15	8	17	5	5.2	0.0	0.0
Savannah	65	150	194	29.93	30.00	− .01	79.8	+ 1.6	100	14	89	61	7	71	31	71	68	74	5.19	− 0.8	11	7,609	sw.	44	ne.	15	14	10	6	4.3	0.0	0.0
Jacksonville	43	209	245	29.95	30.00	− .01	80.0	+ 1.0	96	18	87	67	7	73	21	72	69	75	2.71	− 2.8	8	8,156	ne.	51	sw.	29	12	16	2	4.0	0.0	0.0
Florida Peninsula.							80.8	− 0.1										74	3.69	− 3.2										5.1		
Key West	22	10	64	29.95	29.97	− .02	81.6	− 0.6	90	30	86	73	1	77	14	75	72	73	4.09	− 0.2	10	5,651	se.	22	se.	24	7	20	3	5.0	0.0	0.0
Miami	25	71	79	29.97	30.00		79.7	− 0.7	90	20	85	70	5	74	18	74	71	73	1.14	− 6.8	5	5,477	e.	21	w.	30	9	11	10	5.7	0.0	0.0
Sand Key	23	30	72	29.93	29.96	− .03	80.6		89	24	83	74	3	79	9	75	72	76	0.22		5	7,168	e.	25	e.	9	13	15	2	4.2	0.0	0.0
Tampa	35	79	92	29.66	29.99	− .02	81.0	+ 1.0	94	16	90	66	10	72	23	73	70	74	5.85	− 2.5	10	4,192	ne.	28	se.	25	4	22	4	5.4	0.0	0.0
East Gulf States.							80.7	+ 2.5										70	3.11	− 1.5										5.1		
Atlanta	1,174	190	216	28.81	30.02	+ .01	78.8	+ 3.2	95	27	88	64	2	69	24	68	64	66	1.56	− 2.3	6	6,500	nw.	46	nw.	19	7	12	11	5.9	0.0	0.0
Macon	370	78	87	29.61	30.00	+ .01	80.5	+ 3.4	98	18	91	62	7	70	29	70	65	64	4.00	+ 0.4	12	3,850	s.	22	s.	19	8	13	9	5.6	0.0	0.0
Thomasville	273	49	58	29.70	29.99	− .01	80.6	+ 1.1	98	17	91	62	7	70	26	71	67	69	3.51	− 1.2	11	3,058	ne.	25	s.	30	7	15	8	5.6	0.0	0.0
Pensacola	56	149	185	29.94	30.00	+ .01	80.0	0.0	90	28	85	71	5	75	16	73	71	75	0.40	− 4.5	3	8,386	w.	27	sw.	20	12	15	3	4.5	0.0	0.0
Anniston	741	9	57	29.25	30.03	+ .03	79.7	+ 4.7	98	27	91	62	5	68	29				2.11	− 1.8	6	2,933	se.	20	s.	18	12	15	3	4.2	0.0	0.0
Birmingham	700	11	48	29.27	30.02	+ .03	82.0	+ 2.8	98	27	93	65	5	71	30	70	65	64	1.45	− 2.4	8	3,569	s.	35	s.	24	7	20	3	4.8	0.0	0.0
Mobile	57	125	161	29.94	29.99	.00	81.2	+ 2.1	93	20	89	67	28	74	24	73	70	73	3.97	− 2.0	6	6,604	sw.	50	sw.	30	10	19	1	4.7	0.0	0.0
Montgomery	223	100	112	29.76	30.00	.00	82.4	+ 3.3	99	27	92	67	2	72	25	71	66	62	3.08	− 1.1	3	3,953	w.	30	n.	19	10	15	5	4.9	0.0	0.0
Corinth	469	6					81.4		97	29	93	64	6	70	32				1.95		8		s.				8	20	2		0.0	0.0
Meridian	375	85	93	29.60	29.98	.00	80.6	+ 3.3	96	29	91	64	4	70	27	71	67	68	2.77	− 1.8	6	3,352	sw.	32	e.	4	12	14	4	4.1	0.0	0.0
Vicksburg	247	65	73	29.72	29.99	+ .02	80.2	+ 1.7	93	2	89	66	5	72	23	72	70	78	1.90	− 2.6	12	4,163	se.	24	se.	3	7	15	8	5.6	0.0	0.0
New Orleans	53	76	84	29.93	29.98	.00	81.2	+ 1.6	93	30	88	68	3	74	19	74	71	76	9.44	+ 3.3	14	3,820	se.	25	nw.	28	2	20	8	6.2	0.0	0.0
West Gulf States.							79.6	+ 0.2										76	5.36	+ 1.7										5.6		
Shreveport	249	77	93	29.69	29.95	− .01	80.4	+ 0.8	96	1	89	68	9	72	26	72	69	74	3.34	− 0.2	9	4,877	se.	29	s.	23	16	7	7	4.4	0.0	0.0
Bentonville	1,303	11	44				75.0		90	17	84	58	6	66					9.23		18						7	10	13		0.0	0.0
Fort Smith	457	79	94	29.45	29.92	− .02	78.6	+ 1.8	95	1	88	66	24	70	26	71	69	79	6.50	+ 2.5	16	4,663	e.	39	w.	28	7	7	16	6.4	0.0	0.0
Little Rock	357	136	144	29.58	29.94	− .02	79.0	+ 1.8	94	1	87	67	9	71	23	71	68	75	4.67	+ 0.6	13	5,573	s.	52	s.	6	12	10	8	4.9	0.0	0.0
Brownsville	57	4	26				82.6		97	23	92	68	10	74	25				4.59		8		se.								0.0	0.0
Corpus Christi	20	69	77	29.88	29.90	− .01	81.2	+ 0.6	91	24	86	67	22	76	18	75	73	79	5.89	+ 3.2	11	9,081	s.	66	ne.	22	12	12	6	4.2	0.0	0.0
Dallas	512	109	117	29.36	29.90		78.8		93	1	87	65	8	71	25				5.68		16	6,115	s.	31	se.	12	4	18	8	6.0	0.0	0.0
Fort Worth	670	106	114	29.19	29.89	− .03	78.8	− 1.3	93	30	88	64	8	70	26	70	67	75	2.63	− 0.3	9	7,061	s.	37	nw.	2	7	14	9	5.5	0.0	0.0
Galveston	54	106	114		29.95	.00	80.7	− 0.2	92	1	85	69	9	76	16				4.97	+ 0.2	9	7,884	se.	62	se.	22	5	17	8		0.0	0.0
Groesbeck	461	11	56	29.43	29.90		78.2		93	2	87	66	10	70	23				5.98		18	6,650	se.	42	sw.	12	3	19	8	6.1	0.0	0.0
Houston	138	111	121	29.78	29.92		80.0	− 1.0	96	1	88	67	4	72	23				6.78		16	6,039	se.	60	se.	22	1	21	8	7.9	0.0	0.0
Palestine	510	64	72	29.41	29.93	− .01	78.2	− 0.2	94	1	87	64	9	70	24	71	69	80	11.17	+ 7.2	13	4,785	s.	33	ne.	22	3	17	10	6.5	0.0	0.0
Port Arthur	34	58	66	29.90	29.94		81.0		94	1	86	68	4	76	20	74	72	79	5.12		12	7,270	s.	46	s.	22	19	6	5	3.4	0.0	0.0
San Antonio	701	119	132	29.18	29.89	− .01	81.0	+ 0.6	99	24	90	65	25	71	33	71	67	70	4.59	+ 1.5	7	5,854	se.	31	nw.	22	13	12	5	4.5	0.0	0.0
Taylor	582	55	63	29.33	29.94	+ .02	78.6	− 1.4	94	1	88	64	22	70	23				4.46	+ 0.9	14	5,734	se.	33	n.	22	3	15	12	6.9	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, June, 1921*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee.							**76.4**	**+ 3.4**										**69**	**3.03**	**− 1.2**										**5.2**		
Chattanooga	762	189	213	29.21	30.00	.00	78.9	+ 3.5	94	14	89	65	7	69	25	69	65	68	2.73	− 1.6	9	4,188	w.	38	n.	16	6	17	7	5.7	0.0	0.0
Knoxville	996	102	111	28.97	30.00	.00	78.2	+ 4.8	96	27	88	63	9	68	27	69	65	70	3.07	− 1.1	9	3,753	sw.	40	e.	9	5	9	16	6.6	0.0	0.0
Memphis	399	76	97	29.58	30.00	+ .03	80.6	+ 2.9	95	2	88	66	6	73	22	71	67	69	2.15	− 2.2	9	5,517	sw.	32	n.	28	12	13	5	4.8	0.0	0.0
Nashville	546	168	191	29.42	29.99	.00	80.0	+ 3.7	94	26	90	63	6	70	27	70	66	67	2.29	− 2.1	11	5,227	w.	48	nw.	19	7	16	7	5.4	0.0	0.0
Lexington	989	193	230	28.95	30.00	.00	76.2	+ 3.0	92	26	86	50	5	67	27				2.16	− 1.8	11	8,239	sw.	50	nw.	18	15	9	6	4.2	0.0	0.0
Louisville	525	219	255	29.42	30.00	+ .02	78.2	+ 3.2	93	17	87	54	6	69	28	69	64	67	3.76	− 0.5	8	6,662	sw.	37	n.	19	13	13	4	4.5	0.0	0.0
Evansville	431	139	175	29.52	29.98	+ .01	80.0	+ 4.7	96	2	90	55	6	70	30	70	66	68	2.44	− 1.7	11	6,628	sw.	38	ne.	3	3	23	4	5.5	0.0	0.0
Indianapolis	822	194	230	29.12	29.99	+ .02	76.0	+ 3.6	93	17	86	45	5	66	30	67	63	68	3.22	− 1.1	13	7,055	sw.	29	nw.	21	8	14	8	5.4	0.0	0.0
Royal Center	736	11	55	29.20	29.98		73.8		95	17	85	43	5	63	34				2.33		9	5,996	s.	33	e.	1	7	12	11	5.6	0.0	0.0
Terre Haute	575	96	129	29.34	29.94		77.9		95	13	88	51	5	68	30	68	64	66	3.77		9	5,558	sw.	29	s.	22	8	13	9	5.9	0.0	0.0
Cincinnati	628	11	51	29.32	29.99	.00	75.4	+ 3.7	93	17	86	46	5	65	32				2.35	− 1.6	13	4,279	sw.	23	ne.	4	12	10	8	4.5	0.0	0.0
Columbus	824	179	222	29.15	30.01	+ .02	74.4	+ 3.4	91	13	84	44	5	64	29	67	64	74	2.06	− 1.4	10	6,091	sw.	45	nw.	13	9	17	4	4.5	0.0	0.0
Dayton	899	181	216	29.02	29.95		75.4	+ 3.2	94	13	86	44	5	65	29	66	61	65	1.13	− 2.8	13	6,192	sw.	48	nw.	18	14	14	2	3.9	0.0	0.0
Elkins	1,947	59	67	28.01	30.01	+ .01	68.6	+ 2.0	87	25	80	42	6	57	34	62	60	81	6.08	+ 1.0	13	2,446	w.	34	nw.	17	5	18	7	5.9	0.0	0.0
Parkersburg	638	77	84	29.36	30.01	+ .01	75.0	+ 3.5	92	13	85	50	5	65	32	66	62	68	3.63	− 1.0	10	2,998	se.	30	w.	26	12	11	7	4.8	0.0	0.0
Pittsburgh	842	353	410	29.10	29.99	.00	73.0	+ 1.9	90	17	83	48	5	63	27	64	58	64	5.33	+ 1.4	9	6,256	sw.	47	sw.	28	8	11	11	5.8	0.0	0.0
Lower Lake region.							**69.2**	**+ 2.2**										**68**	**2.15**	**− 1.4**										**4.7**		
Buffalo	767	247	280	29.17	29.99	+ .02	66.6	+ 1.5	86	25	74	46	5	59	34	59	54	66	1.52	− 1.6	6	8,858	sw.	46	sw	11	11	9	10	5.3	0.0	0.0
Canton	448	10	61	29.48	29.94		65.7	− 0.1	90	22	77	38	5	54	36				1.66	− 1.8	7	6,145	w.	38	w.	11	20	7	3	3.2	0.0	0.0
Oswego	335	76	91	29.60	29.97	.00	65.0	+ 1.2	84	22	73	43	5	57	30	60	56	73	0.80	− 2.6	6	5,548	w.	29	ne.	1	12	9	9	4.5	0.0	0.0
Rochester	523	86	102	29.43	29.99	+ .02	68.4	+ 2.3	90	26	78	43	5	58	34	60	53	59	0.83	− 2.3	5	5,361	nw.	29	w.	13	12	11	7	4.5	0.0	0.0
Syracuse	597	97	113	29.35	29.99	+ .02	67.1	+ 0.2	89	22	77	41	5	57	29				3.83	− 0.1	8	6,555	nw.	40	nw.	13	9	11	10	5.4	0.0	0.0
Erie	714	130	166	29.23	29.98	.00	69.2	+ 2.2	87	27	77	47	5	61	27	63	58	68	3.48	− 0.3	4	7,630	ne.	37	w.	13	10	16	4	4.5	0.0	0.0
Cleveland	762	190	201	29.18	29.99	+ .01	69.8	+ 1.9	88	26	77	50	5	63	28	63	58	68	2.38	− 1.3	9	7,151	ne.	35	ne.	4	11	12	7	4.9	0.0	0.0
Sandusky	629	62	103	29.33	30.00	+ .02	72.0	+ 3.2	94	21	79	52	5	65	25				1.73	− 2.1	9	6,668	ne.	35	ne.	3	6	18	6	5.0	0.0	0.0
Toledo	628	208	243	29.32	30.00	+ .03	72.8	+ 3.4	94	17	82	41	5	64	25	64	60	66	1.34	− 2.0	7	7,918	ne.	39	w.	27	13	15	2	4.0	0.0	0.0
Fort Wayne	856	113	124	29.09	29.99		73.1	+ 4.6	91	17	84	43	5	63	37	65	61	68	3.58		10	5,356	e.	44	sw.	18	10	12	8	5.2	0.0	0.0
Detroit	730	218	245	29.23	30.01	+ .04	71.4	+ 3.6	95	17	81	41	5	62	29	65	61	74	3.94	0.0	11	6,696	e.	40	nw.	27	13	9	8	4.7	0.0	0.0
Upper Lake region.							**67.8**	**+ 5.3**										**70**	**1.90**	**− 1.4**										**4.8**		
Alpena	609	13	92	29.35	30.01	+ .05	63.4	+ 3.1	90	22	72	36	5	54	31	59	55	72	1.80	− 1.8	5	6,533	se.	40	nw.	3	16	7	7	4.2	0.0	0.0
Escanaba	612	54	60	29.32	29.98	+ .04	65.4	+ 4.8	89	22	73	37	4	57	25	60	56	73	1.13	− 2.5	6	5,323	s.	34	n.	3	19	5	6	3.8	0.0	0.0
Grand Haven	632	54	89	29.31	29.97	+ .01	69.8	+ 5.1	87	30	79	40	4	61	27	63	58	66	1.99	− 0.5	6	6,030	e.	50	sw.	12	9	17	4	4.9	0.0	0.0
Grand Rapids	707	70	87	29.23	29.98	+ .01	73.4	+ 5.3	93	26	84	41	4	63	27	64	59	63	3.62	+ 1.1	7	3,576	se.	19	ne.	28	6	14	10	6.0	0.0	0.0
Houghton	684	62	99	29.26	29.98	+ .04	65.8	+ 6.4	94	16	77	37	4	55	33				0.88	− 2.6	8	6,263	e.	32	w.	22	8	19	3	4.6	0.0	0.0
Lansing	878	11	62	29.06	29.98		70.6	+ 3.2	94	17	83	37	5	58	33	63	59	69	3.24	− 0.2	11	2,903	s.	18	sw.	18	10	15	5	5.3	0.0	0.0
Ludington	637	60	66	29.30	29.98		67.2		87	19	75	36	5	59	31	61	56	68	0.59		4	5,613	s.	28	s.	27	14	12	4	4.0	0.0	0.0
Marquette	734	77	111	29.21	30.00	+ .06	65.2	+ 6.7	92	30	75	39	1	56	38	60	57	77	1.52	− 2.0	8	5,456	s.	44	s.	17	9	10	11	5.5	0.0	0.0
Port Huron	638	70	120	29.31	29.99	+ .02	68.0	+ 4.2	91	17	78	42	5	58	30	62	59	75	1.01	− 2.2	5	5,895	ne.	33	nw.	11	9	18	3	3.8	0.0	0.0
Saginaw	641	69	77	29.31	30.00		69.9		96	17	80	40	5	59	31	63	59	69	3.64	+ 1.0	10	4,846	ne.	24	sw.	11	11	6	13	5.5	0.0	0.0
Sault Sainte Marie	614	11	52	29.31	30.00	+ .04	63.0	+ 5.4	91	30	74	37	4	52	33	57	52	69	0.56	− 2.2	6	4,502	se.	37	nw.	3	16	9	5	3.7	0.0	0.0
Chicago	823	140	310	29.11	29.98	+ .02	73.8	+ 7.5	95	17	80	49	4	68	23	66	61	67	1.57	− 2.1	6	6,681	ne.	30	n.	3	11	14	5	4.8	0.0	0.0
Green Bay	617	109	144	29.32	29.97	+ .02	70.6	+ 5.5	93	17	80	41	4	61	28	62	58	68	0.71	− 2.8	7	6,173	s.	33	sw.	12	7	15	8	5.7	0.0	0.0
Milwaukee	681	125	139	29.25	29.98	+ .03	69.8	+ 6.3	92	18	77	45	5	62	28	63	59	70	0.61	− 3.1	9	5,356	ne.	30	sw.	10	9	12	9	5.2	0.0	0.0
Duluth	1,133	11	47	28.76	29.96	+ .04	62.6	+ 4.9	89	26	72	37	4	53	38	57	54	76	4.38	− 0.2	10	7,691	ne.	35	nw.	2	13	10	7	4.5	0.0	0.0
North Dakota.							**69.3**	**+ 5.6**										**68**	**3.18**	**− 0.5**										**5.0**		
Moorhead	940	50	58	28.91	29.91	+ .01	70.4	+ 6.1	100	30	81	38	4	60	33	64	59	70	1.40	− 2.7	7	5,545	s.	23	se.	11	9	13	8	5.1	0.0	0.0
Bismarck	1,674	8	57	28.15	29.89	+ .02	71.2	+ 7.0	107	30	83	43	4	59	42	61	55	62	0.92	− 2.6	9	7,514	e.	39	sw.	20	10	13	7	5.0	0.0	0.0
Devils Lake	1,482	11	44	28.33	29.88	.00	66.9	+ 4.3	96	30	77	35	3	57	30	61	58	73	4.70	+ 1.2	14	6,581	se.	33	ne.	18	12	10	8	4.9	0.0	0.0
Ellendale	1,457	10	56	28.37	29.90		68.9		98	30	80	39	4	58	36				3.40		8	8,836	se.	48	se.	29	12	10	8	5.0	0.0	0.0
Grand Forks	835	12	89				68.5		100	30	79	32	4	58	43	63			2.54		10		se.	60	sw.	26	16	10	4		0.0	0.0
Williston	1,878	41	48	27.89	29.82	− .04	68.6	+ 5.1	95	14	79	44	2	58	35	61	57	69	5.68	+ 2.1	14	6,339	e.	36	e.	18	8	16	6	5.0	0.0	0.0
Upper Mississippi Valley.							**76.0**	**+ 5.0**										**71**	**3.42**	**− 1.0**										**5.4**		
Minneapolis	918	102	208		29.89		74.4		99	30	84	46	4	65	28				3.81	− 0.2	8	7,010	se.	36	se.	1	10	11	9	5.1	0.0	0.0
St. Paul	837	236	261	29.05	29.94	+ .02	73.5	+ 6.1	97	30	83	47	4	64	26				4.70	+ 0.3	6	7,034	se.	40	se.	1	12	12	6	4.3	0.0	0.0
La Crosse	714	11	48	29.19	29.94	+ .01	73.1	+ 4.2	94	29	83	43	5	63	28				2.31	− 2.1	8	2,397	se.	17	s.	12	8	10	12	6.1	0.0	0.0
Madison	974	70	78	28.95	29.98	+ .04	72.2	+ 4.9	91	29	81	45	4	64	24	65	61	71	3.52	− 0.6	10	4,520	se.	27	se.	25	5	10	15	6.8	0.0	0.0
Wausau	1,247	4		28.66	29.97		69.6		93	17	80	36	4	59	31				4.01		11		se.				9	12	9	5.7	0.0	0.0
Charles City	1,015	10	49	28.90	29.95	+ .04	73.8	+ 5.0	95	30	84	45	5	63	30	67	64	74	2.93	− 2.2	12	3,431	se.	19	sw.	14	8	20	2	4.8	0.0	0.0
Davenport	606	71	79	29.31	29.96	+ .02	76.8	+ 5.9	95	30	87	46	5	67	29	68	64	71	3.64	− 0.5	12	4,076	e.	26	sw.	20	8	11	11	5.8	0.0	0.0
Des Moines	861	84	97	29.02	29.91	− .01	76.3	+ 5.9	96	28	86	50	5	67	28	68	64	69	4.66	− 0.3	9	3,754	sw.	30	n.	28	9	9	12	6.0	0.0	0.0
Dubuque	698	81	96	29.24	29.97	+ .04	75.0	+ 5.4	93	19	84	44	5	66	28	66	62	68	3.54	− 1.0	8	3,537	se.	17	n.	3	6	13	11	5.9	0.0	0.0
Keokuk	614	64	78	29.29	29.96	+ .02	77.5	+ 5.0	96	19	87	49	5	68	29	68	64	69	2.53	− 1.8	9	4,090	sw.	31	w.	20	6	12	12	6.0	0.0	0.0
Cairo	356	87	93	29.58	29.95	− .02	79.2	+ 4.0	94	18	88	60	6	70	25	70	67	73	1.83	− 2.5	11	5,254	sw.	32	sw.	24	5	16	9	5.9	0.0	0.0
Peoria	609	11	45	29.31	29.97	+ .02	76.8	+ 5.9	95	20	87	48	5	66	30	68	65	73	2.17	− 2.1	10	3,347	s.	20	nw.	20	17	10	3	3.5	0.0	0.0
Springfield, Ill	644	10	91	29.28	29.94	− .01	77.6	+ 5.3	95	13	87	49	5	68	30	69	65	72	5.41	+ 1.1	11	4,790	w.	23	e.	5	7	16	7	5.6	0.0	0.0
Hannibal	534	74	109	29.38	29.94	− .01	77.5	+ 4.2	96	13	86	52	5	69	27				3.52	0.0	14	5,005	sw.	34	s.	1	10	9	11	5.3	0.0	0.0
St. Louis	567	265	303	29.36	29.95	.00	78.4	+ 3.3	94	13	87	53	5	70	25	69	65	68	2.31	− 2.2	12	7,813	s.	48	n.	20	11	14	5	4.1	0.0	0.0
Missouri Valley.							**75.6**	**+ 4.7**										**69**	**4.33**	**0.0**										**4.6**		
Columbia, Mo.	781	11	84	29.12	29.93	− .02	75.7	+ 1.2	92	19	84	51	5	67	29				3.18	− 1.2	11	4,132	s.	20	ne.	4	9	12	9	5.1	0.0	0.0
Kansas City	963	161	181	28.91	29.91	− .01	77.0	+ 4.0	94	28	85	54	5	69	25	69	65	71	9.67	+ 5.0	12	6,015	s.	30	n.	2	15	6	9	4.5	0.0	0.0
St. Joseph	967	11	49	28.89	29.89		77.4		95	17	87	54	5	68	29	68	65	71	4.37		11	4,529	e.	22	w.	16	17	4	9	4.0	0.0	0.0
Springfield, Mo.	1,324	98	104	28.58	29.96	+ .01	74.2	+ 1.9	88	1	82	56	5	66	24	69	67	83	9.68	+ 4.5	17	5,977	se.	31	w.	19	11	12	7	4.4	0.0	0.0
Iola	984	11	50	28.88	29.90	− .03	76.4	+ 3.0	93	17	86	57	5	67	28				8.41	+ 3.7	17	3,694	s.	24	n.	20	7	10	13	6.3	0.0	0.0
Topeka	987	92	107				76.2	+ 2.7	94	28	85	55	5	67	28				6.62	+ 1.8	13	5,898	s.	44	sw.	7	8	11	11	5.5	0.0	0.0
Drexel	1,299	10	53	28.55	29.90		74.7		96	30	85	52	5	64	28	68	64	72	2.80		8	5,962	s.	33	se.	1	11	11	8	4.8	0.0	0.0
Lincoln	1,189	11	84	28.66	29.89	− .01	76.4	+ 4.8	100	28	87	55	4	66	30	68	64	71	4.43	+ 0.1	9	5,714	s.	37	s.	16	11	7	12	5.3	0.0	0.0
Omaha	1,105	115	122	28.77	29.92	+ .01	77.4	+ 5.8	98	28	86	55	5	68	26	69	65	70	3.57	− 1.5	10	4,243	se.	22	n.	1	11	11	8	4.8	0.0	0.0
Valentine	2,598	47	54	27.25	29.91	+ .05	72.6	+ 5.5	99	29	85	47	20	60	36	61	55	60	1.65	− 2.2	7	6,739	s.	36	sw.	19	12	15	3	4.4	0.0	0.0
Sioux City	1,135	94	164	28.73	29.91	+ .01	76.0	+ 6.6	96	28	86	53	4	66	30	67	62	63	2.10	− 1.8	5	6,565	s.	43	sw.	14	9	17	4	4.9	0.0	0.0
Huron	1,306	59	74	28.54	29.91	+ .03	74.0	+ 7.4	99	28	86	42	4	62	34	65	61	66	0.78	− 3.0	5	6,294	se.	27	nw.	27	21	8	1	2.3	0.0	0.0
Pierre	1,572	70	75	28.24	29.86	− .01	76.0	+ 7.1	104	29	88	48	4	64	34	65	60	62	0.54	− 2.5	4	6,227	se.	34	w.	20	16	7	7	4.1	0.0	0.0
Yankton	1,233	49	57	28.61	29.90	+ .01	75.8	+ 6.4	101	28	87	49	4	65	32				1.36	− 2.9	7	4,211	s.	27	s.	14	10	18	2	4.4	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, June, 1921*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Northern Slope.							64.6	+ 3.0										60	2.03	− 0.2										4.6		
Billings	3,140	5	.....	.....	.....	.....	69.4	.....	97	13	86	37	1	52	45	.....	.....	.....	2.42	.....	7	.....	.....	.....	.....	.....	9	18	3	.....	0.0	0.0
Havre	2,505	11	44	27.29	29.88	+ .03	67.8	+ 5.4	97	13	82	44	3	54	42	57	50	63	2.00	− 0.8	12	4,587	sw.	40	sw.	29	10	13	7	5.0	0.0	0.0
Helena	4,110	87	112	25.78	29.89	+ .01	63.7	+ 3.1	91	13	76	42	17	51	39	52	44	56	1.65	− 0.5	9	5,464	sw.	39	sw.	24	8	11	11	5.8	0.0	0.0
Kalispell	2,973	48	56	26.88	29.88	− .01	60.9	+ 2.1	83	29	73	38	15	49	36	51	43	58	1.22	− 0.5	14	3,754	nw.	30	sw.	24	9	15	6	4.7	0.0	0.0
Miles City	2,371	26	48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rapid City	3,259	50	58	26.57	29.91	+ .06	69.8	+ 6.0	97	29	81	48	4	58	39	59	52	58	3.36	− 0.2	12	5,677	w.	37	nw.	18	10	14	6	4.9	0.0	0.0
Cheyenne	6,088	84	101	24.04	29.89	+ .05	61.6	+ 0.1	88	30	73	42	18	50	37	52	46	62	2.92	+ 1.4	12	7,356	se.	43	nw.	18	14	9	7	4.4	0.0	0.0
Lander	5,372	60	68	24.65	29.89	+ .04	63.5	+ 2.2	93	29	77	41	20	50	40	52	44	55	2.57	+ 1.5	10	3,441	sw.	46	sw.	2	13	12	5	4.4	0.0	0.0
Sheridan	3,790	10	47	26.06	29.88	.....	66.6	.....	97	11	80	40	1	53	47	57	51	63	1.94	.....	11	4,294	nw.	38	sw.	13	20	7	3	2.8	0.0	0.0
Yellowstone Park	6,200	11	48	23.90	29.90	+ .04	57.8	+ 1.8	84	29	71	33	2	44	37	47	40	60	1.13	− 0.5	11	4,955	s.	32	sw.	11	4	20	6	5.6	0.0	0.0
North Platte	2,821	11	51	27.07	29.94	+ .08	71.8	+ 3.4	95	30	84	50	20	60	34	62	58	69	1.39	− 1.9	8	2,831	se.	21	e.	27	13	11	6	4.2	0.0	0.0
Middle Slope.							72.6	+ 0.7										68	4.39	+ 1.2										5.6		
Denver	5,292	106	113	24.74	29.90	+ .06	67.2	+ 0.8	93	30	78	47	4	56	31	54	46	53	3.26	+ 1.8	10	5,006	s.	34	se.	18	14	11	5	4.3	0.0	0.0
Pueblo	4,685	80	86	25.28	29.87	+ .04	68.9	− .01	94	30	82	45	19	56	37	56	48	56	7.14	+ 5.7	11	4,154	e.	34	w.	29	12	12	6	4.9	0.0	0.0
Concordia	1,392	50	58	28.47	29.91	+ .01	75.8	+ 3.1	95	28	86	57	5	66	30	67	62	67	3.35	− 1.6	13	4,725	s.	30	s.	16	5	16	9	6.0	0.0	0.0
Dodge City	2,509	11	51	27.38	29.92	+ .05	72.8	− .03	94	27	83	57	2	63	30	65	61	74	4.48	+ 1.2	13	6,082	se.	30	s.	15	12	10	8	4.8	0.0	0.0
Wichita	1,358	139	158	28.49	29.89	− .02	74.7	+ 0.4	90	17	83	59	5	66	23	68	66	78	4.31	− 0.4	12	7,630	s.	48	sw.	21	9	13	8	5.4	0.0	0.0
Altus	1,410	5	.....	.....	.....	.....	77.4	.....	99	30	88	61	6	66	31	.....	.....	.....	6.26	.....	15	.....	se.	.....	.....	.....	10	1	19	.....	0.0	0.0
Broken Arrow	765	11	52	29.10	29.91	.....	75.7	.....	91	19	83	63	24	68	22	.....	.....	.....	10.86	.....	16	7,689	s.	45	n.	23	3	11	16	7.0	0.0	0.0
Muskogee	652	4	.....	.....	.....	.....	78.4	.....	96	1	88	65	24	69	27	.....	.....	.....	11.02	.....	20	.....	e.	.....	.....	.....	7	13	10	.....	0.0	0.0
Oklahoma City	1,214	10	47	28.66	29.90	− .01	76.0	+ 0.3	91	1	84	62	7	68	24	69	67	79	3.80	+ 0.7	17	7,209	s.	34	n.	9	5	9	16	7.0	0.0	0.0
Southern Slope.							75.4	− 1.7										69	6.20	+ 3.5										4.6		
Abilene	1,738	10	52	28.11	29.87	− .01	77.8	− 0.4	97	2	88	61	21	68	31	68	64	69	8.22	+ 5.0	14	6,841	s.	44	ne.	9	7	13	10	5.7	0.0	0.0
Amarillo	3,676	10	49	26.24	29.90	+ .05	70.2	− 1.8	93	1	81	51	6	60	34	63	59	76	7.75	+ 4.8	16	6,661	se.	36	s.	1	12	17	1	4.1	0.0	0.0
Del Rio	944	64	71	28.89	29.85	.00	81.7	− 0.4	100	25	92	64	21	72	31	.....	.....	.....	3.25	+ 0.8	7	8,213	se.	37	sw.	12	15	11	4	3.9	0.0	0.0
Roswell	3,566	75	85	26.31	29.84	+ .04	72.0	− 4.3	94	25	85	49	6	59	38	60	54	62	5.58	+ 3.5	9	5,137	s.	48	se.	17	9	16	5	4.8	0.0	0.0
Southern Plateau.							74.1	− 0.5										36	0.74	+ 0.4										2.5		
El Paso	3,762	110	133	26.10	29.74	− .01	79.6	0.0	101	25	92	56	5	67	32	59	43	37	0.79	+ 0.2	4	8,028	e.	53	nw.	5	22	8	0	2.5	0.0	0.0
Santa Fe	7,013	57	66	23.28	29.80	− .01	62.9	− 3.3	87	28	75	40	5	51	35	51	44	56	2.85	+ 1.8	8	5,475	se.	38	sw.	28	14	10	6	4.6	0.0	0.0
Flagstaff	6,908	10	59	23.37	29.80	+ .02	58.8	− 0.5	87	30	76	28	18	42	46	44	.....	.....	1.03	.....	4	5,808	nw.	37	w.	11	22	5	3	2.6	0.0	0.0
Phoenix	1,108	76	81	28.59	29.71	− .03	84.8	+ .04	110	22	101	54	18	68	44	60	39	24	0.04	− 0.1	1	3,761	w.	24	se.	12	23	4	3	1.9	0.0	0.0
Yuma	141	9	54	29.58	29.72	− .02	84.4	− 0.3	109	22	102	58	17	67	42	63	48	37	T.	0.0	0	3,194	sw.	18	w.	16	25	5	0	1.1	0.0	0.0
Independence	3,957	9	41	25.90	29.84	+ .06	74.3	+ 0.0	100	11	89	44	16	60	37	53	34	27	0.01	− 0.1	1	4,604	s.	34	sw.	22	23	5	2	2.5	0.0	0.0
Middle Plateau.							67.5	+ 1.9										40	0.31	− 0.2										3.5		
Reno	4,532	74	81	25.44	29.87	+ .01	64.5	+ 3.5	92	22	80	36	17	49	39	49	37	45	0.23	0.0	3	5,199	w.	37	w.	2	18	7	5	3.3	T.	0.0
Tonopah	6,090	12	20	24.04	29.82	.....	67.7	.....	92	11	80	32	16	55	31	50	35	34	0.08	− 0.4	4	5,401	w.	37	nw.	15	18	12	0	3.2	T.	0.0
Winnemucca	4,344	18	56	25.58	29.90	+ .02	65.2	+ 1.9	93	10	80	32	16	50	39	52	42	53	0.82	+ 0.2	3	4,669	sw.	39	s.	22	18	4	8	3.7	0.2	0.0
Modena	5,479	10	43	24.58	29.81	− .01	64.8	+ 1.6	94	11	82	32	17	48	43	46	26	30	0.01	− 0.4	1	7,707	sw.	55	s.	15	22	7	1	2.2	0.0	0.0
Salt Lake City	4,360	163	203	25.55	29.83	− .02	71.2	+ 2.9	96	28	83	47	18	60	31	54	42	39	0.08	− 0.7	3	5,460	nw.	44	w.	23	16	9	5	3.9	0.0	0.0
Grand Junction	4,602	60	68	25.33	29.84	+ .01	72.0	− 0.6	98	28	86	42	1	58	36	54	41	40	0.63	+ 0.2	7	4,556	se.	29	se.	12	11	11	8	4.5	0.0	0.0
Northern Plateau.							66.9	+ 2.0										52	0.60	− 0.6										5.1		
Baker	3,471	48	53	26.40	29.94	− .01	61.3	+ 2.7	89	22	75	38	15	48	42	51	44	61	0.81	− 0.4	9	4,062	se.	34	sw.	23	8	17	5	5.1	0.0	0.0
Boise	2,739	78	86	27.08	29.88	− .03	68.2	+ 2.2	94	28	82	43	15	55	39	56	48	54	0.09	− 0.8	3	3,567	w.	29	w.	23	13	13	4	4.0	0.0	0.0
Lewiston	757	40	48	29.11	29.90	− .04	69.7	+ 0.6	94	22	83	46	15	56	44	.....	.....	.....	1.05	0.0	8	2,711	e.	28	se.	23	7	10	13	6.0	0.0	0.0
Pocatello	4,477	60	68	25.43	29.86	− .01	66.2	+ 2.0	93	28	80	40	18	52	36	52	43	50	0.58	− 0.4	8	4,893	se.	36	sw.	24	13	16	1	3.8	0.0	0.0
Spokane	1,929	101	110	27.89	29.90	− .04	65.8	+ 2.4	92	23	77	45	18	54	33	53	44	51	0.42	− 1.2	6	5,134	sw.	30	s.	23	5	17	8	6.2	0.0	0.0
Walla Walla	991	57	65	28.86	29.92	− .04	70.4	+ 2.2	98	23	82	50	15	59	33	56	45	45	0.67	− 0.5	7	3,589	s.	37	s.	23	9	14	7	5.2	0.0	0.0
North Pacific Coast Region.							59.8	+ 1.6										78	2.27	+ 0.3										7.2		
North Head	211	11	56	29.78	30.00	+ .01	55.7	+ 0.7	62	25	59	49	13	52	10	55	54	94	3.10	+ 1.3	15	12,049	s.	50	s.	26	4	12	14	6.5	0.0	0.0
Port Angeles	29	8	53	29.99	30.02	.....	55.8	.....	70	23	63	42	2	48	26	.....	.....	.....	0.96	− 0.3	12	3,762	sw.	24	w.	30	1	7	22	8.0	0.0	0.0
Seattle	125	215	250	29.88	30.01	+ .01	59.8	− 0.3	75	23	67	49	17	53	23	54	50	73	1.29	− 0.4	13	5,961	s.	39	sw.	13	1	10	19	7.7	0.0	0.0
Tacoma	213	113	120	29.78	30.00	− .03	60.0	+ 0.6	77	5	68	46	2	52	29	55	51	75	1.64	− 0.5	13	3,949	n.	24	sw.	13	0	15	15	7.6	0.0	0.0
Tatoosh Island	86	7	57	29.89	29.99	− .03	54.4	+ 1.4	64	23	58	47	12	51	15	53	51	91	6.78	+ 2.6	18	7,807	s.	42	s.	26	2	10	18	7.5	0.0	0.0
Yakima	1,071	4	.....	.....	.....	.....	67.0	.....	94	23	83	38	14	51	40	.....	.....	.....	0.27	.....	5	.....	nw.	.....	.....	2	11	11	8	.....	0.0	0.0
Medford	1,425	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Portland, Oreg.	153	68	106	29.83	29.99	− .05	64.4	+ 3.1	83	6	73	50	15	56	27	56	51	66	1.36	− 0.4	12	4,344	nw.	22	sw.	14	2	7	21	7.8	0.0	0.0
Roseburg	510	9	57	29.46	30.00	− .03	64.8	+ 3.9	90	23	78	44	1	52	39	56	50	68	0.76	− 0.3	10	2,352	n.	18	w.	15	6	19	5	5.1	0.0	0.0
Middle Pacific Coast Region.							64.2	+ 1.8										67	0.28	− 0.1										3.5		
Eureka	62	73	89	30.00	30.07	+ .02	57.2	+ 2.6	69	10	62	46	3	52	16	54	51	84	1.30	+ 0.2	6	4,488	n.	25	n.	30	7	10	13	6.3	0.0	0.0
Point Reyes Light	490	7	18	29.42	29.93	.....	53.4	+ 0.6	71	22	58	47	1	49	20	.....	.....	.....	0.02	.....	1	21,269	nw.	61	nw.	5	10	7	13	5.6	0.0	0.0
Red Bluff	332	50	56	29.52	29.87	− .01	76.2	+ 0.5	108	22	90	48	16	62	36	61	50	46	0.06	− 0.4	1	4,401	nw.	23	nw.	21	26	4	0	2.0	0.0	0.0
Sacramento	69	106	117	29.81	29.88	− .01	71.9	+ 3.0	105	22	87	47	1	57	38	61	55	62	0.05	− 0.1	1	6,253	s.	24	s.	13	27	3	0	1.4	0.0	0.0
San Francisco	155	208	243	29.78	29.95	− .01	61.4	+ 4.4	90	21	69	49	1	54	27	55	51	75	T.	− 0.2	0	8,294	w.	43	w.	15	18	11	1	3.4	0.0	0.0
San Jose	141	12	110	29.83	29.98	.....	65.0	.00	97	21	78	44	1	52	41	.....	.....	.....	T.	− 0.1	0	5,040	nw.	28	nw.	15	22	8	0	2.1	0.0	0.0
South Pacific Coast Region.							63.7	+ 0.6										68	0.00	− 0.1										3.4		
Fresno	327	89	98	29.52	29.86	+ .01	76.0	+ 0.2	107	22	91	50	1	61	35	59	46	41	0.01	− 0.1	1	7,760	nw.	31	nw.	14	25	4	1	1.3	0.0	0.0
Los Angeles	338	159	191	29.54	29.90	.00	65.6	− 1.1	85	19	74	54	1	58	24	59	56	79	0.01	− 0.1	1	3,734	sw.	18	sw.	16	12	13	5	4.4	0.0	0.0
San Diego	87	62	70	29.81	29.92	− .02	63.1	− 0.7	79	19	68	54	17	58	22	59	56	82	T.	− 0.1	0	3,943	w.	18	nw.	25	9	10	11	5.7	0.0	0.0
San Luis Obispo	201	32	40	29.73	29.94	− .03	64.4	+ 4.0	98	21	77	43	16	52	40	54	50	72	T.	− 0.1	0	3,605	nw.	24	w.	15	25	4	1	2.0	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.91	30.00	.....	80.4	.....	92	5	86	72	29	75	17	.....	.....	.....	2.20	− 3.7	9	8,198	e.	34	e.	9	4	16	10	6.2	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	.....	29.83	− .01	79.8	− 0.2	90	23	85	72	29	75	15	.....	.....	.....	7.86	+ 0.4	22	4,276	nw.	26	s.	25	0	7	23	.....	0.0	0.0
Colon	36	7	97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Alaska.																																
Juneau	80	11	49	.....	.....	.....	56.6	.....	78	3	66	39	1	47	35	50	46	71	1.86	.....	10	3,022	se.	20	se.	7	5	11	14	6.5	0.0	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, June, 1921.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	Inches.	Inches.	Inches.	°F.	°F.	°F.	°F.	°F.	°F.	Inches.	Inches.	Inches.
St. Johns, N. F.	125	29.66	29.80	−0.11	52.4	+0.8	62.1	42.7	82	36	5.21	+1.61	0.0
Sydney, C. B. I.	48	29.84	29.89	.06	56.0	+0.6	66.0	46.1	84	36	0.66	−2.37	0.0
Halifax, N. S.	88	29.79	29.89	− .06	57.6	−0.1	66.9	48.3	82	40	3.80	+0.04	0.0
Yarmouth, N. S.	65	29.82	29.89	− .06	55.1	+0.1	62.4	47.8	75	39	1.88	−0.88	0.0
Charlottetown, P. E. I.	38	29.82	29.86	− .06	58.5	+1.1	67.4	49.6	81	37	1.12	−1.55	0.0
Chatham, N. B.	28	29.86	29.89	.00	60.0	0.0	71.5	48.6	86	36	0.98	−2.48	0.0
Father Point, Que.	20	29.83	29.85	− .02	53.7	+0.7	63.2	44.2	74	34	1.50	−1.42	0.0
Quebec, Que.	296	29.58	29.89	− .03	63.1	+1.9	74.3	52.0	87	41	1.74	−1.91	0.0
Montreal, Que.	187	29.71	29.91	− .03	67.3	+2.4	77.5	57.1	92	44	2.14	−1.39	0.0
Stonecliffe, Ont.	489	29.33							93		1.21	−1.95	0.0
Ottawa, Ont.	236	29.68	29.94	.00	66.4	+1.1	78.7	54.1	94	41	4.51	+1.59	0.0
Kingston, Ont.	285	29.66	29.96		65.4	+2.0	74.1	56.7	86	45	1.30	−1.13	0.0
Toronto, Ont.	379												
Cochrane, Ont.	930				63.0		77.0	49.0	95	31	0.76		0.0
White River, Ont.	1,244	28.64	29.93	− .01	60.1	+1.4	76.2	44.0	92	22	1.48	−0.74	0.0
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.29			62.2	+1.8	71.9	52.5	85	35	4.98	+2.63	0.0
Parry Sound, Ont.	688	29.29	29.97	+ .01	66.2	+4.5	78.8	53.7	96	38	1.65	−0.77	0.0
Port Arthur, Ont.	644	29.27	29.98	+ .04	61.8	+5.4	72.2	51.4	87	33	2.31	−0.42	0.0
Winnipeg, Man.	760	29.06	29.87	− .02	67.7	+5.5	78.9	56.6	94	32	1.56	−1.73	0.0
Minnedosa, Man.	1,690	28.10	29.88	− .01	64.7	+5.1	75.4	54.0	89	28	1.95	−1.05	0.0
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.63	29.83	− .04	64.8	+4.9	76.0	53.5	87	26	4.90	+1.48	0.0
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759				68.1		81.7	54.6	96	30	2.02		0.0
Swift Current, Sask.	2,392	27.33	29.88	+ .01	66.7	+6.7	80.0	53.5	95	34	2.04	−0.63	0.0
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.31	29.86	− .01	64.7	+7.0	76.4	52.9	86	30	3.03	+0.52	0.0
Battleford, Sask.	1,592	28.12	29.82	− .04	66.4	+6.9	79.9	53.0	86	31	1.70	−1.61	0.0
Kamloops, B. C.	1,262	28.65	29.86	− .01	60.9	−2.9	78.4	53.4	87	43	0.65	−0.77	0.0
Victoria, B. C.	230	29.72	29.97	− .04	56.4	+0.1	63.2	49.6	70	46	1.24	+0.04	0.0
Barkerville, B. C.	4,180												
Trinagle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

61552—21——4

SEISMOLOGICAL REPORTS FOR JUNE, 1921.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, Aug. 3, 1921.]

TABLE 1.—*Noninstrumental earthquake reports, May-June, 1921.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1921.	H. m.		° ′	° ′			Sec.			
May 12	4 05	Trona	35 45	117 20	1, 2	4	1-3	Faint	Felt by many	L. W. Mumford.
June 12	3 24	San Jose	37 15	121 53	3	1		None	Felt by several	A. H. Palmer.
		Santa Clara	37 15	121 55	3	1	1	....do	....do	A. Newlin.
	3 25	Salinas	36 41	121 39	3-4	1	20	....do	Felt by many	E. D. Eddy.
		UTAH.								
June 2	21 30	Cedar City	37 40	113 00	2-3	1	2	Rumbling	Felt by several	T. Lawrence.

TABLE 2.—*Instrumental seismological reports, June, 1921.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols see REVIEW for January, 1921, p. 47.]

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			H. m. s.	Sec.	μ	μ	Km.	
June 17		P_E	8 10 56	2				
		S_E	8 11 36					
		S_N	8 11 41					
		L_E	8 11 46	2				
		L_N	8 11 46					
		M_E	8 12 22		100			
		M_N	8 12 07			80		
		C_E	8 12 31					
		C_N	8 12 23					
		F_E	8 24 ..					
		F_N	8 28 ..					
17		P_N	10 20 19					
		e_E	10 20 47					
		L_E	10 21 18					
		L_N	10 21 05					
		M_E	10 21 22		40			
		M_N	10 21 19			20		
		C_E	10 21 32					
		C_N	10 21 50					
		F_E	10 32 ..					
		F_N	10 30 ..					

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			H. m. s.	Sec.	μ	μ	Km.	
June 1					100	100		Tremors.
30					100	100		Do.

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			H. m. s.	Sec.	μ	μ	Km.	
June 17		e	8 25 50					Phases not recognizable.
		F	8 35 ..					
17		e	10 34 50					Do.
		F	10 40 ca.					
25		e	2 25 45					
		F	2 35 ca.					
28								Doubtful evidences of quake about 14:30; mostly lost in changing sheets.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			H. m. s.	Sec.	μ	μ	Km.	
June 17		e_E	8 27 48	12				Phases not well defined: a slight renewal of activity from 10:36 to 10:40 may be the local shock recorded at Tucson.
		e_N	8 27 37	11				
		M_E	8 30 54	8	*1,000			
		M_N	8 28 50	10		*1,000		
		C_E	8 31 32	8				
		C_N	8 31 ..	9				
		F_E	8 32 ..					
		F_N	8 33 ..					
25		P_N	2 15 52					L may come as late as 2:21:44.
		S_N	2 19 29					
		L_E	2 20 20	12				
		L_N	2 20 20	17				
		M_E	2 22 44	8	*3,300			
		M_N	2 23 22	10		*3,500		
		C_E	2 26 36	7				
		C_N	2 23 58	8				
		F_E	2 48. ..	6				
		F_N	2 48 ..	7				
28		e_N	14 09 23					Phases indistinct; E obscured by overlapping of record.
		e_N	14 18 20					
		F_N	14 48 ..					

*Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			H. m. s.	Sec.	μ	μ	Km.	
June 4		e	1 40 15					Phases not recognizable.
		F	1 55 ca.					
15		eP	19 02 05					
		S?	19 03 45					
		eL	19 15 40					
		F	19 40 ..					
17		P	8 22 05					Do.
		F	9 ca.					
17		e	10 26 ..					Do.
		F	10 50 ..					
25		P?	2 16 15					
		S?	2 21 40					
		F	3 10 ca.					
28		P	14 18 38					
		S	14 28 35					
		L	14 54 40	30				
		L	15 15 02	18				
		L	15 15 10	15				
		F	16 ca.					
30		P?	2 17 42					
		S?	2 23 30					
		L	2 28 30	15				
		F	3 ca.					

TABLE 2.—*Instrumental seismological reports, June, 1921*—Contd.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. June 25		i_E	2 25 32	5				Phases poorly defined; distinct phases, both components, at 2:26:21, possibly P of a second shock.
		e_N	2 25 29					
		e_E	2 28 31	8				
		e_N	2 28 39	12				
		M_E	2 28 40		10			
		M_N	2 29 11	12		20		
		C_N	2 30 ..					
		F_E	2 33 ..					
		F_N	2 36 ..					

CANAL ZONE. *Panama Canal, Balboa Heights.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. June 1		P	14 04 20				85 *ca.*	Direction probably SW.
		S	14 04 30					
		M_E	14 04 32		*3,000			
		M_N	14 04 33			*4,000		
		F_E	14 05 20					
		F_N	14 05 30					
6		P_E	0 10 44				320 *ca.*	Probably westerly.
		P_N	0 10 36					
		S_E	0 11 18					
		S_N	0 11 12					
		L_E	0 11 25					
		L_N	0 11 22					
		M_E	0 11 30		*3,500			
		M_N	0 11 20			*2,500		
		F_E	0 15 50					
		F_N	0 16 30					
13								Slight disturbance between 18:26 and 18:30.

* Trace amplitude.

CANADA. *Dominion Observatory, Ottawa.*

Date		Phase	H. m. s.	Sec.	μ.	μ.	Km.	Remarks
1921. June 4		e_N	1 37 30					No trace on vertical.
		e	1 43 49					
		L	2 39 ..					
		F	2 55 ..					
15		$e?_E$	19 01 30					Do.
		eL	19 08 17					
		F	19 50 ..					
17		$e?_E$	8 25 12					
		i	8 26 44					
		L_{EV}	8 29 24					
		F	8 55 ..					
17		i_N	10 35 51					
		e_E	10 36 ..					
		L_E	10 38 24					
		F	10 52 *ca.*					
25		$e?_E$	2 17 54					
		eL_{NEV}	2 23 39					
		L	2 31 ..	irreg.				
		L	2 37 30	do.				
		F	3 05 ..					
28		e_{EV}	14 17 45					Curious increase of period in L waves instead of usual maximum period first.
		i_{NV}	14 19 49					
		i_V	14 20 49					
		eL?	14 29 43					
		L_E	14 37 ..	16				
		L_E	14 41 ..	11				
		L_E	14 55 ..	28				
		L_E	15 05 ..	21				
		L_E	15 24 ..	18				
		F	16 10 ..					
30		O	2 10 08				3,190	
		P	2 16 22					
		S	2 21 19					
		eL_E	2 24 30	18				
		eL_N	2 25 30	18				
		L_E	2 31 30	12				
		F	3 00 ..					

No earthquakes were recorded at the following stations during June, 1921:

ALASKA. U. S. C. & G. S. Magnetic Observatory, Sitka.
COLORADO. Regis College, Denver (formerly College of the Sacred Heart).
MISSOURI. St. Louis University, St. Louis.
NEW YORK. Fordham University, New York.
PORTO RICO. U. S. C. & G. S. Magnetic Observatory, Vieques.
VERMONT. U. S. Weather Bureau, Vermont.

Reports for June, 1921, have not been received from the following stations:

ALABAMA. Spring Hill College, Mobile.
DISTRICT OF COLUMBIA. Georgetown University, Washington.
MASSACHUSETTS. Harvard University, Cambridge.
NEW YORK. Canisius College, Buffalo; Cornell University, Ithaca.
CANADA. Dominion Meteorological Service, Toronto and Victoria.

TABLE 3.—*Late reports (instrumental).*

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. May 1		P	5 42 38	4			1,620	
		S_E	5 45 26					
		eS_N	5 45 47					
		L_E	5 46 10	29				
		eL_N	5 47 07					
		M_E	5 47 20	16	500			
		M_N	5 48 30			460		
		C_E	5 52 ..	9				
		C_N	5 53 ..					
		F_E	6 15 ..	8				
		F_N	6 07 ..					
14		P_E	22 13 16	4				Phases not well defined.
		P_N	22 12 53	5				
		L_E	22 16 17	27				
		eL_N	22 17 32	15				
		M_E	22 18 14	14	90			
		M_N	22 18 26	12		60		
		C_E	22 20 ..					
		C_N	22 21 ..					
		F_E	22 35 ..					
		F_N	22 26 ..					

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. May 1		e_N	6 04 39					E not in operation during May.
		F_N	6 11 ..			30		
28		e_N	20 55 53					
		M_N	20 59 17			10		
		F_N	21 02 ..					

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.
1921. May 22		P	18 23 14	2,4			
		L_E	18 23 39				
		L_N	18 23 38				
		M_E	18 24 21		50		
		M_N	18 24 04			100	
		F_E	18 31 ..	6			
		F_N	18 30 ..	5			

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. May 1		P	5 46 19	5				P_N and L_N are well defined, but L_N has some of the characteristics of S.
		e_E	5 57 10					
		eL_E	5 59 49					
		L_N	5 56 49					
		M_E	6 00 17		110			
		M_N	5 59 23	12		60		
		C_N	6 14 ..					
		F_E	6 11 ..					
		F_N	6 43 ..					
14		P_E	22 16 39					
		P_N	22 16 34	3				
		S_E	22 21 24					
		L_N	22 23 44	6				
		M_E	22 27 49		10			
		M_N	22 30 10			20		
		C_E	22 34 ..					
		C_N	22 33 ..					
		F_E	22 42 ..					
		F_N	22 40 ..					
28		e_E	21 12 37					
		e_N	21 10 55					
		e_E	21 13 18					
		e_N	21 13 22	11				
		M_E	21 13 54		10			
		M_N	21 14 08	12		40		
		F_E	21 33 ..					
		F_N	21 34 ..					

TABLE 3.—*Late reports (instrumental)*—Continued.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1921.			H. m. s.	Sec.	μ	μ	Km.	
May 1	....	S_N	5 55 25	......	......	......	......	First three phases fairly well marked; consistent with records from other stations; E out of adjustment.
		$SR1_N$	5 59 24	......	......	......	......	
		$SR2_N$	6 00 32	......	......	......	......	
		eL_N	6 02 29	9	......	......	......	
		M_N	6 01 06	9	......	*6,000	......	
		C_N	6 10 ..	8	......	......	......	
		F_N	7 20 ..	7	......	......	......	
3	....	L_E	11 00 35	20	......	......	......	
		L_N	11 00 20	23	......	......	......	
		M_E	11 01 08	......	*500	......	......	
		M_N	11 01 53	......	......	*200	......	
		F_E	11 04 ..	......	......	......	......	
		F_N	11 06 ..	......	......	......	......	
4	....	eP_E	21 29 10	......	......	......	......	P_E doubtful; N ill-defined.
		L_E	21 29 20	20	......	......	......	
		L_N	21 29 40	8	......	......	......	
		M_E	21 30 18	12	*1,500	*400	......	
		F_E	21 34 ..	12	......	......	......	
		F_N	21 34 ..	......	......	......	......	
12	....	iP_E	3 49 45	......	......	......	5,900	
		iS_E	3 57 18	......	......	......	......	
		e_N	4 00 ..	......	......	......	......	
		L_E	4 05 49	31	......	......	......	
		L_N	4 06 04	......	......	......	......	
		M_E	4 14 24	16	*2,000	......	......	
		M_N	4 14 51	17	......	*1,000	......	
		C	4 16 ..	16	......	......	......	
		F_E	4 48 ..	16	......	......	......	
		F_N	4 40 ..	......	......	......	......	
14	....	iP	11 40 56	......	......	......	......	
		$SR1_N$	11 54 23	......	......	......	......	
		L_E	12 01 53	28	......	......	......	
		M_E	12 02 05	......	*500	......	......	
		F_E	13 11 ..	......	......	......	......	
		F_N	11 55 ..	......	......	......	......	
14	....	P_E	20 27 19	......	......	......	6,000	
		P_N	20 27 31	......	......	......	......	
		iS_E	20 35 05	......	......	......	......	
		iS_N	20 35 01	......	......	......	......	
		$SR2_E$	20 40 42	......	......	......	......	
		eL_E	20 44 13	19	......	......	......	
		M_E	20 42 48	12	*2,000	......	......	
		M_N	20 47 41	......	......	*1,500	......	

1921.			H. m. s.	Sec.	u	u	Kw.	
May 14		C_N	20 49 ..	18	......	......	......	
		F_E	21 35 ..	......	......	......	......	
		F_N	21 31 ..	......	......	......	......	
14	....	e_E	22 30 32	......	......	......	......	Difficult; initial phase may be SR1.
		e_N	22 30 40	......	......	......	......	
		e_E	22 32 05	......	......	......	......	
		e_N	22 34 00	......	......	......	......	
		L_N	22 35 35	......	......	......	......	
		M_E	22 35 00	......	*1,500	......	......	
		M_N	22 35 53	10	......	*1,400	......	
		F_E	22 52 ..	......	......	......	......	
		F_N	22 46 ..	......	......	......	......	
16	....	e_E	15 32 42	......	......	......	......	No distinct phases.
		e_N	15 38 04	......	......	......	......	
		M_E	15 39 27	10	*900	......	......	
		M_N	16 00 43	14	......	*500	......	
		F	16 09 ..	......	......	......	......	
21	....	P_E	8 53 51	......	......	......	8,000	
		S_E	9 03 31	......	......	......	......	
		iS_N	9 03 16	......	......	......	......	
		$eSR1_E$	9 08 31	......	......	......	......	
		L_E	9 17 36	25	......	......	......	
		M_E	9 27 49	18	*1,100	......	......	
		M_N	9 13 01	......	......	*500	......	
		F_E	9 56 ..	16	......	......	......	
		F_N	9 35 ..	......	......	......	......	
21	....	iP	22 41 02	11	......	......	2,200	
		S_E	22 44 46	18	......	......	......	
		S_N	22 44 38	10	......	......	......	
		L_E	22 46 29	11	......	......	......	
		L_N	22 46 12	11	......	......	......	
		M_E	22 51 13	......	*2,700	......	......	
		M_N	22 46 55	9	......	*2,500	......	
		C_E	22 56 ..	14	......	......	......	
		C_N	22 59 ..	......	......	......	......	
		F_E	24 24 ..	10	......	......	......	
		F_N	24 23 ..	10	......	......	......	
28	....	e_E	21 10 30	......	......	......	......	
		e_N	21 10 23	......	......	......	......	
		M_E	21 12 25	10	*1,500	......	......	
		M_N	21 11 40	10	......	*1,300	......	
		F_E	21 18 ..	......	......	......	......	
		F_N	21 22 ..	......	......	......	......	

* Trace amplitude.

Chart I. Hydrographs of Several Principal Rivers, June, 1921.

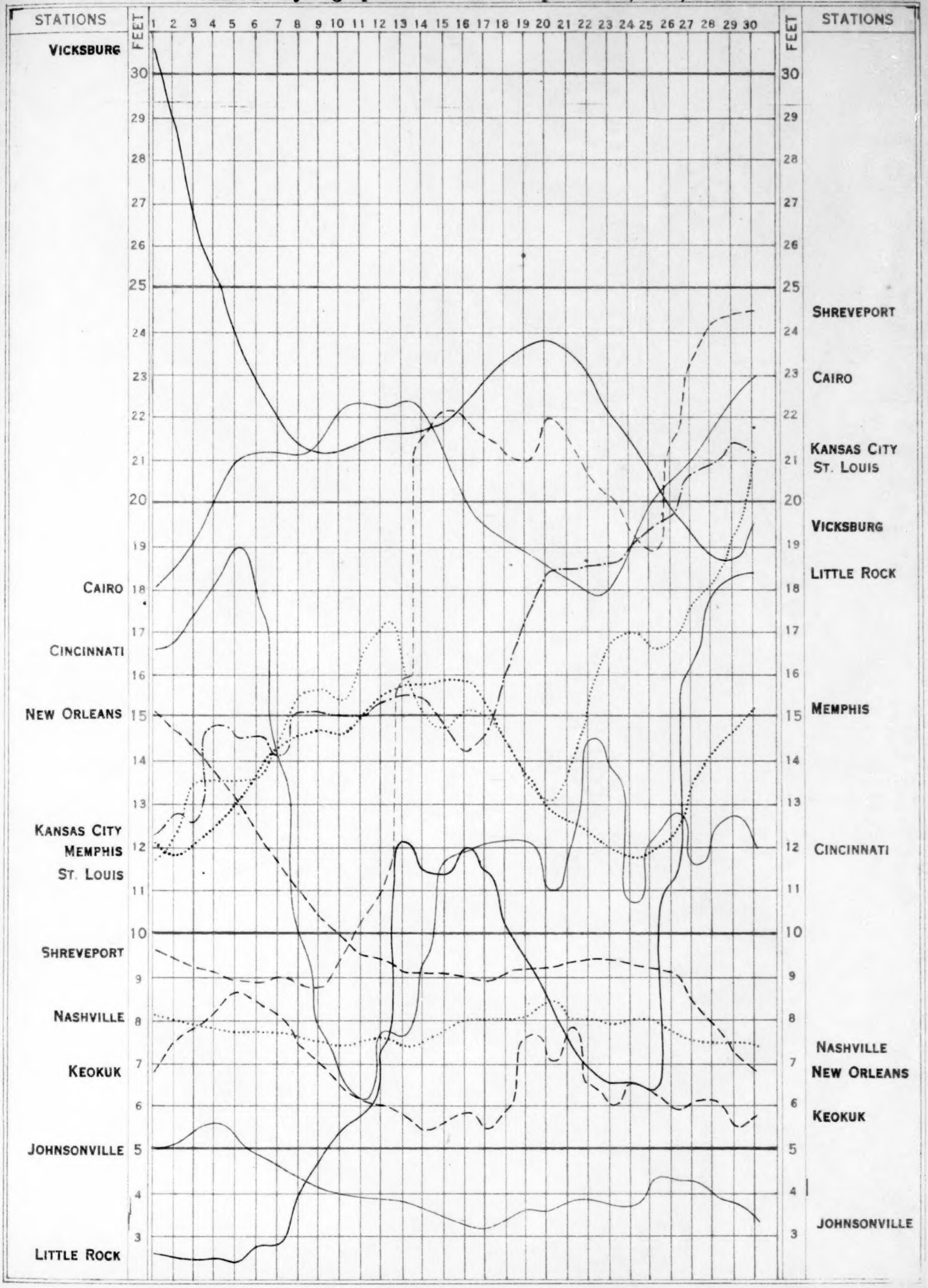


Chart II. Tracks of Centers of High Areas, June, 1921.
(Plotted by Wilfred P. Day.)

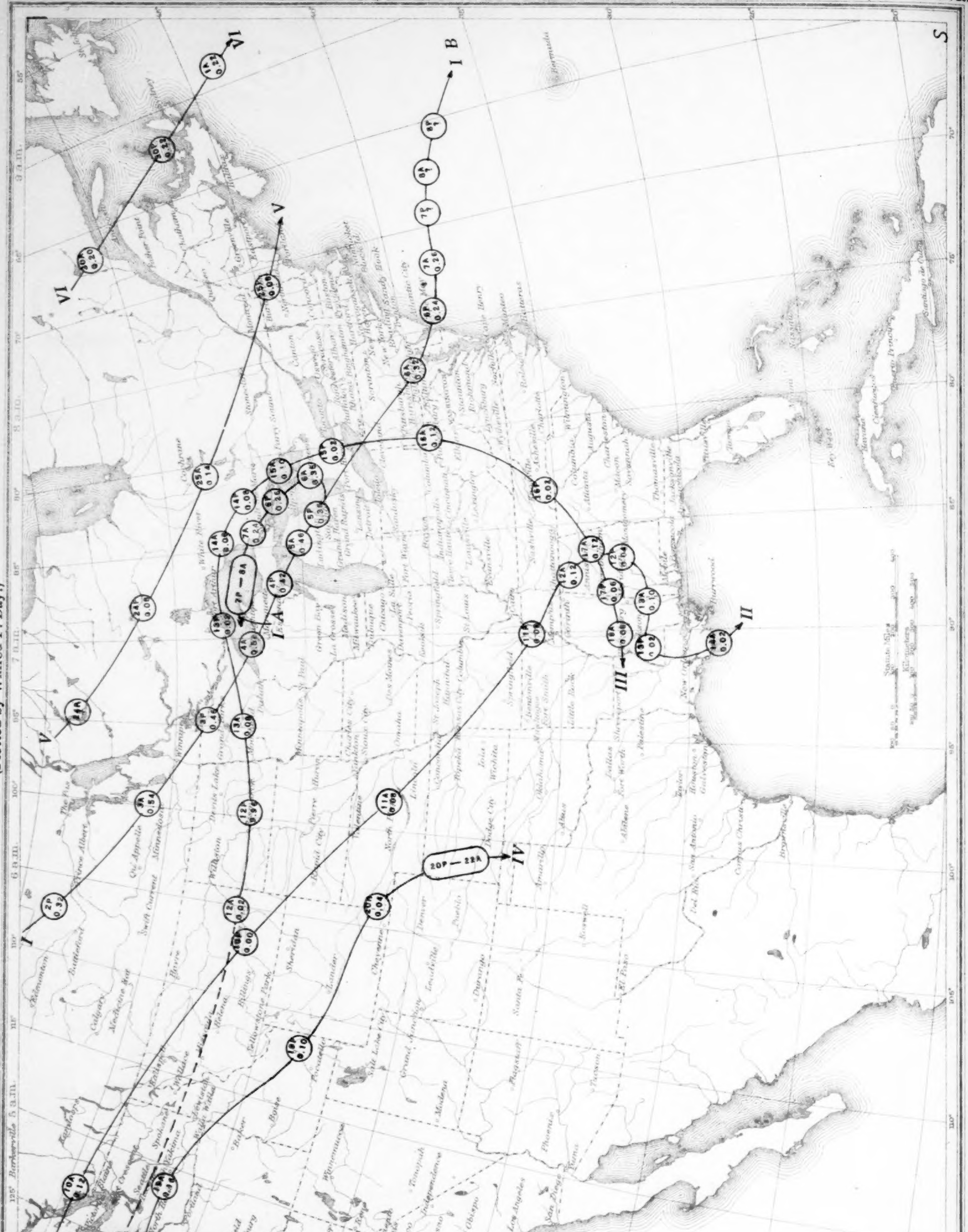


Chart III. Tracks of Centers of Low Areas, June, 1921.
(Plotted by Wilfred P. Day.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, June, 1921.

Chart V. Total Precipitation, Inches, June, 1921.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, June, 1921.

Chart VII. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, June, 1921.

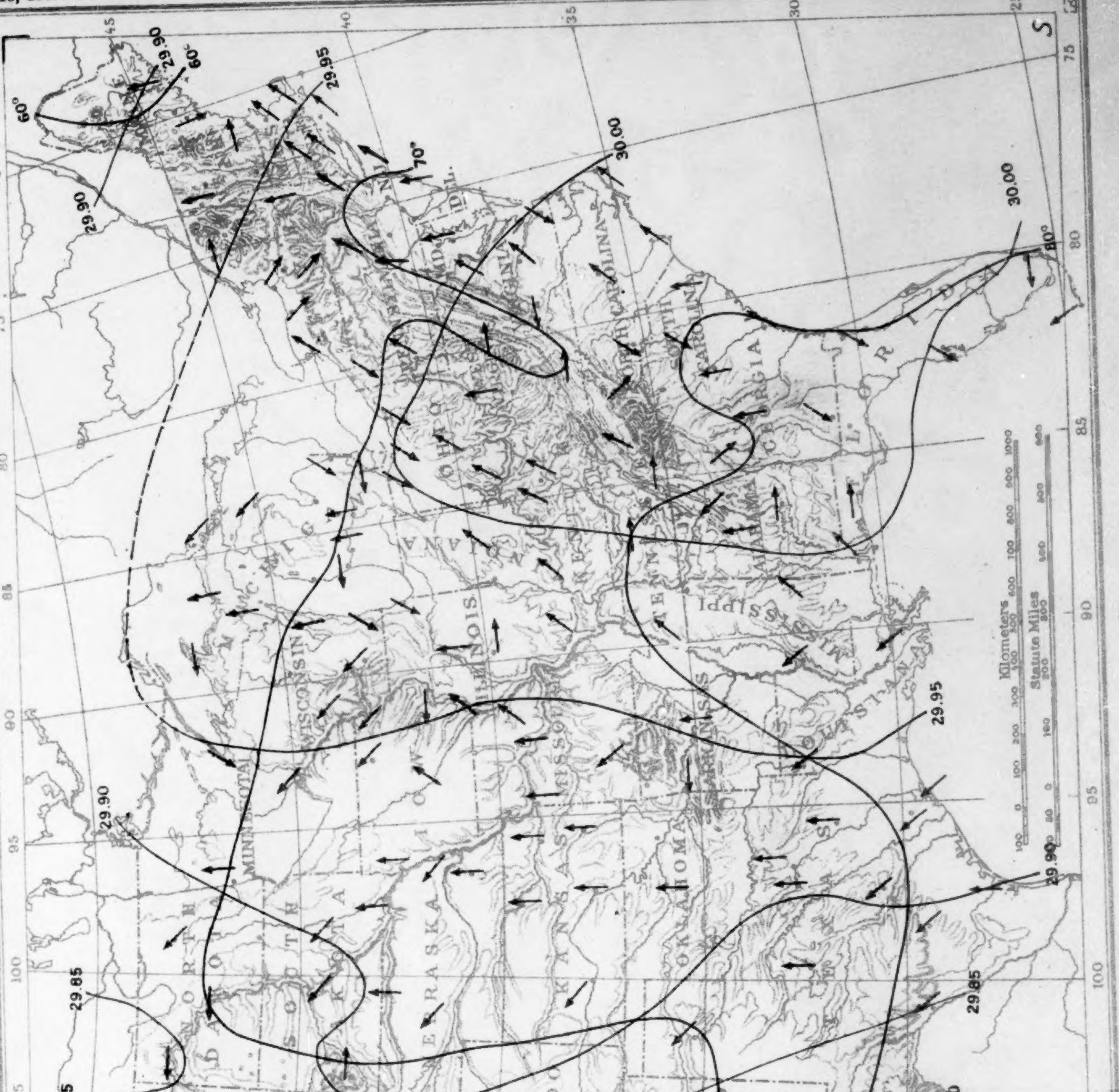


Chart IX. Weather Map of North Atlantic Ocean, June 20, 1921.

Chart IX. Weather Map of North Atlantic Ocean, June 20, 1921.
(Plotted by F. A. Young.)

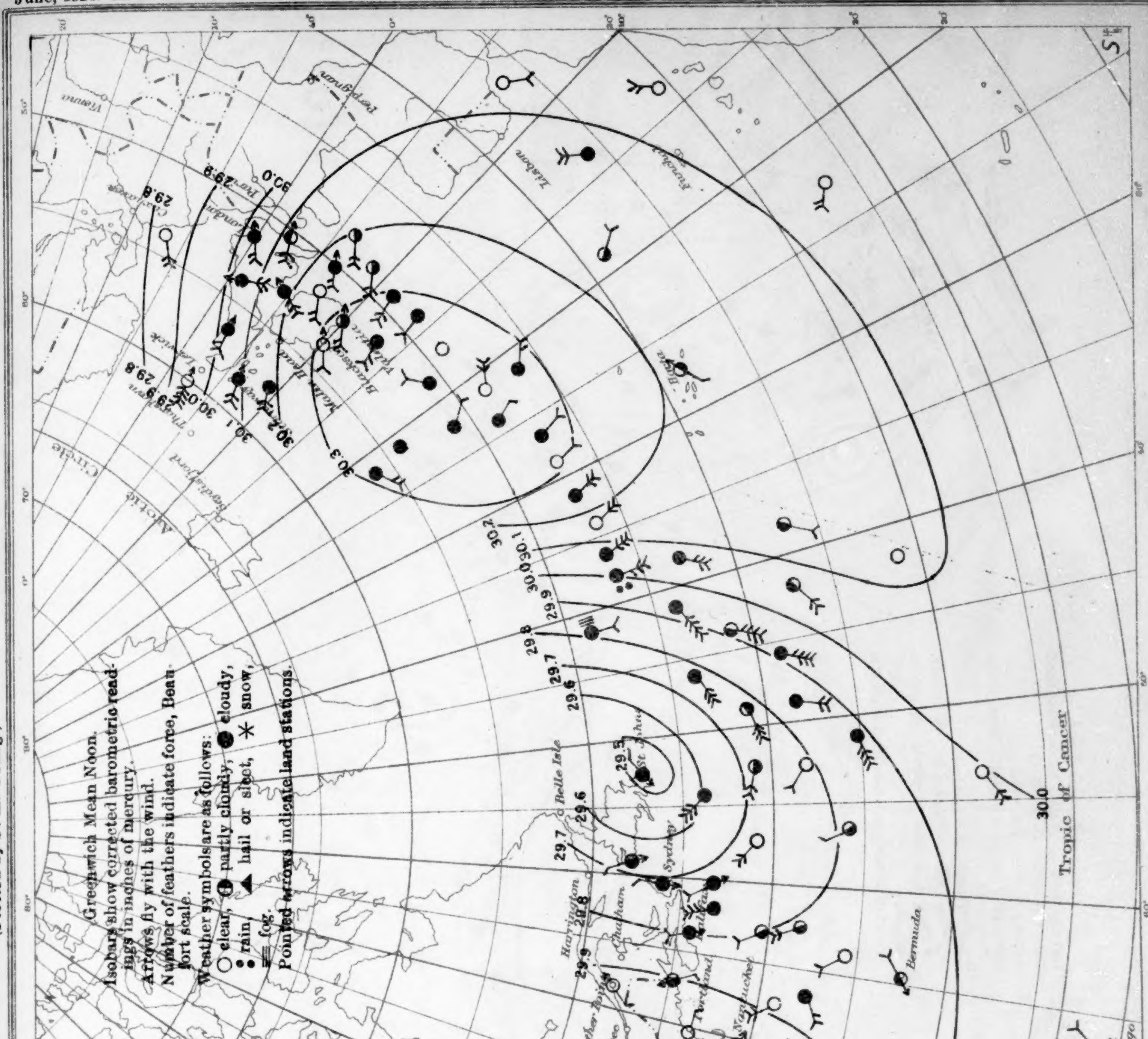


Chart X. Weather Map of North Atlantic Ocean, June 21, 1921.
(Plotted by F. A. Young.)

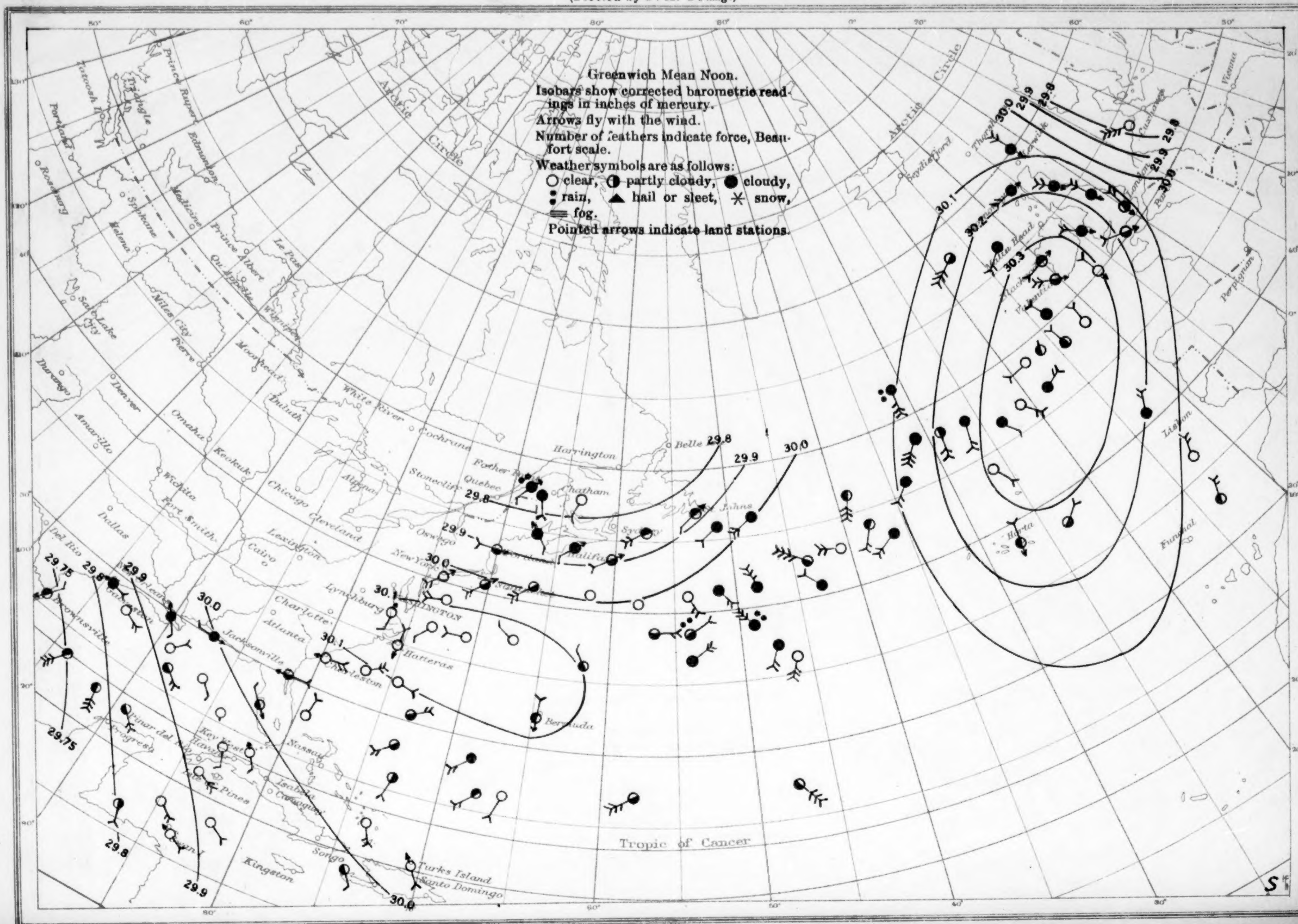
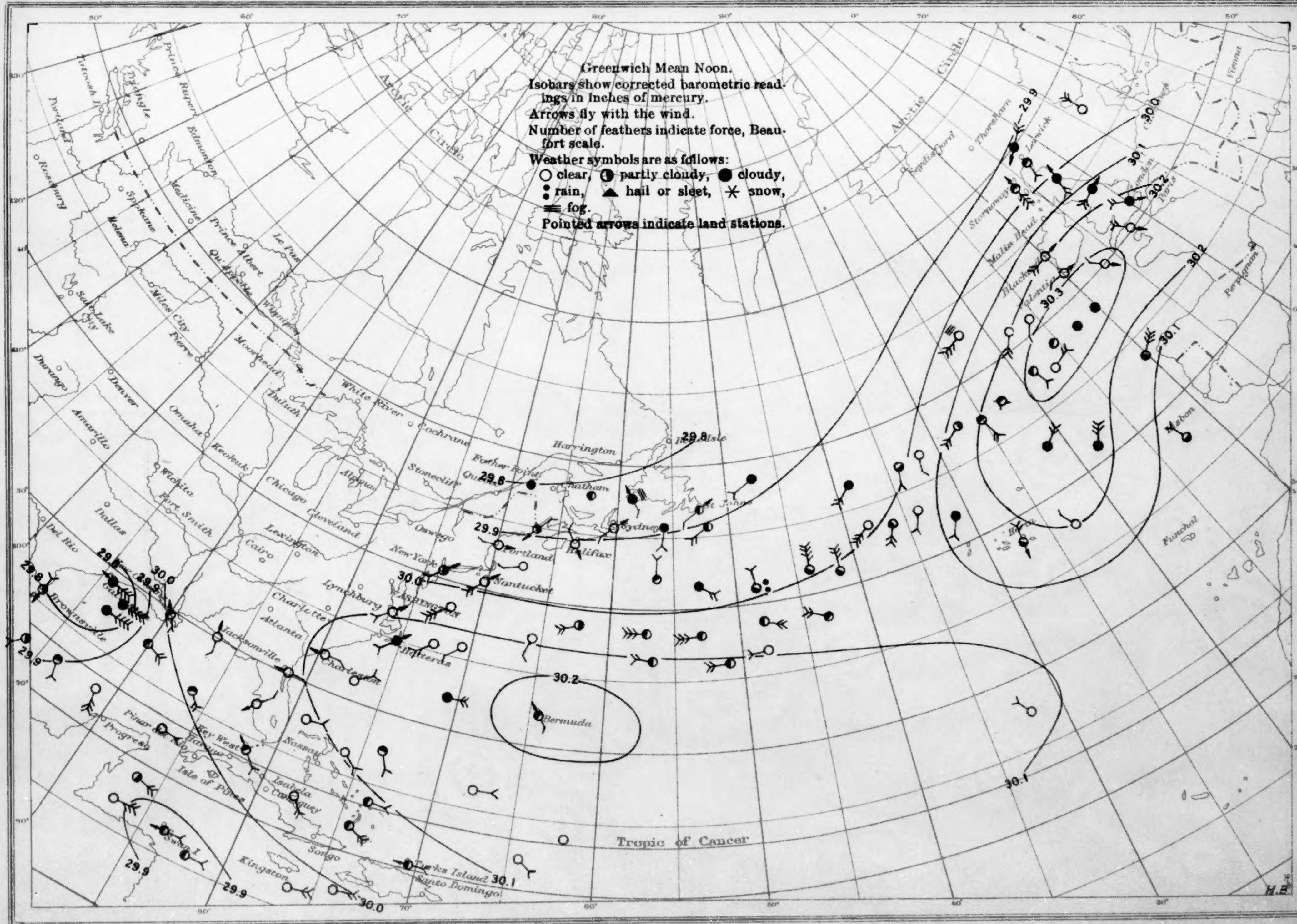
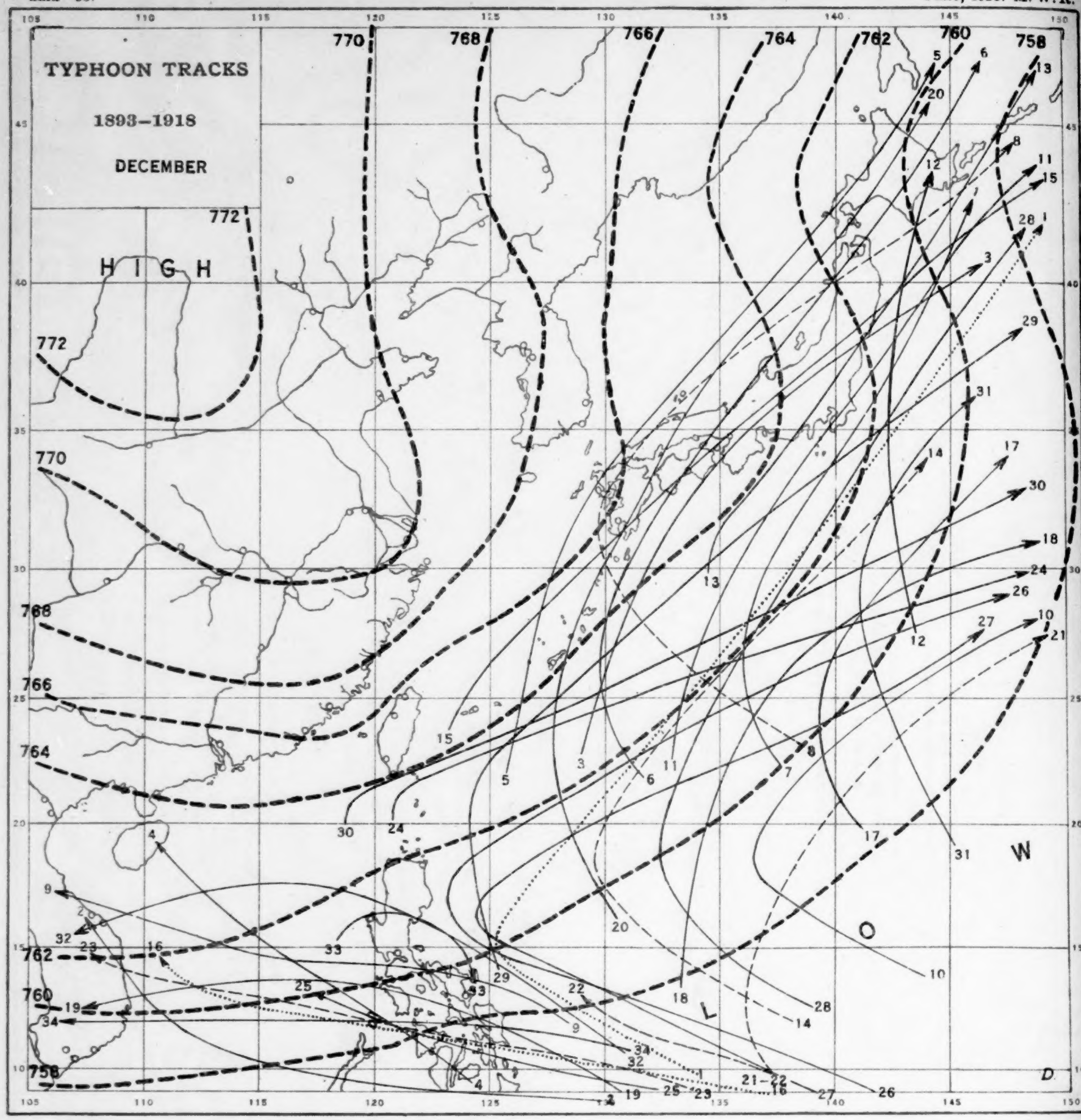


Chart XI. Weather Map of North Atlantic Ocean, June 22, 1921.

Chart XI. Weather Map of North Atlantic Ocean, June 22, 1921.

(Plotted by F. A. Young.)





DECEMBER.—*One chart: 34 tracks; a little more than one instance every year.*

The radiating point, or birth-place of the tropical storms, appears to have a movement backward to the East, far to the S of Guam and the SE of Yap. The depressions, rare now and of decreasing intensity, are scattered, in the SW corner of the map, between Cape Padaran and Vinh, to the S of the Gulf of Tongking. Another bundle follows the same curve as during November, between the Marianas and Japan, most of them go away on the Pacific to the N. of the Bonin group.

A glance at the arrangement of the isobars gives an obvious reason for the general retreat of the oceanic storms; the line of 764^{mm} starts from the Gulf of Tongking, surrounds Formosa and the Loochoos, and crossing the Kii Channel, cuts in two halves the Sea of Japan along the 135th meridian. But very often the NE monsoon reaches the force of a full gale and there are records of powerful mail steamers taking five days for the run from Hongkong to Shanghai.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director, Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]

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ECONOMIES IN PRINTING.

Contributions intended for publication in the REVIEW must in all cases conform to the regulations of the Department of Agriculture with respect to effecting economies in the public printing. A memorandum in regard to preparing manuscripts for publication has just been issued by the Department, and an excerpt is reproduced below for the information of all concerned.

Authors will be expected to prepare their manuscripts, with the understanding that once the manuscript leaves the author's hands it is in final form and not subject to further changes of text in galley or page proof. With the adoption of this policy it will be necessary that authors consult workers on related subjects in other Bureaus before finally submitting their manuscript for publication, and all matters as to which there is difference of opinion must be settled in advance.

JUNE, 1921.

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* Separates to be published.

† In marine separate.